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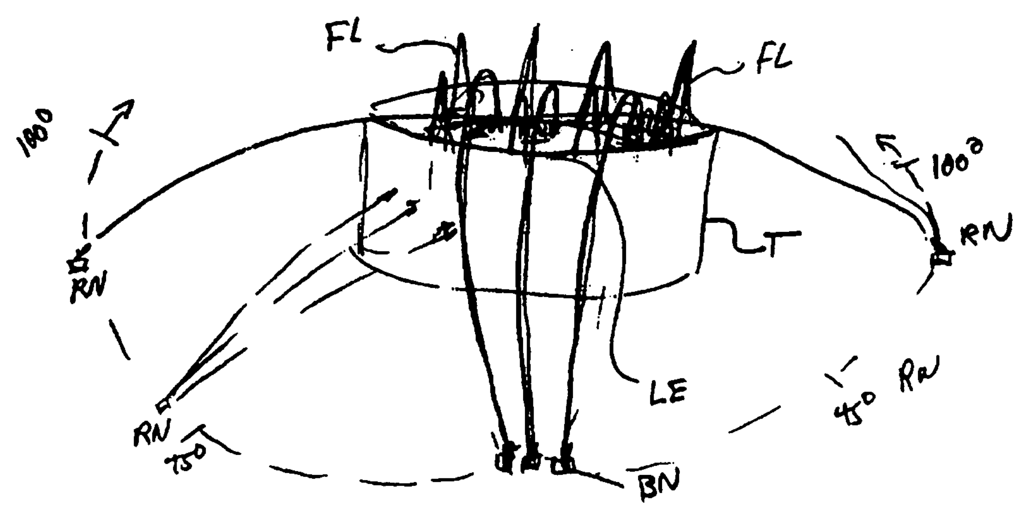

(57) Abstract

Methods for extinguishing tank fires including establishing a foam blanket and subsequently cooling inner and/or outer tank wall portions (T), as well as applying dry power to residual flames. Methods also include improving the foam blanket established from staged nozzles through creating side footprints at the site for correcting footprint range, length, and width, and through correcting predicted footprint and foam run for variations in factors such as fluid height, wind conditions, nozzle stream width, head pressure, percent of foam concentrate, characteristics of the burning fluid, the type of foam and the temperature of the burning fluid.

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METHODS FOR EXTINGUISHING TANK FIRES

Field of Invention

This invention relates to improved methods for extinguishing tank fires, including tank fires involving crude and high vapor pressure flammable liquids and fluids having low boiling points and/or low auto-ignition points, with particular attention to high octane fuels.

BACKGROUND OF INVENTION

The past 18 years has witnessed several changes in the fire fighting industry. Foam delivery nozzles have enlarged their capacity from 500-1,000 gpm to 6,000-10,000 gpm, or higher. Fire hoses have increased in size from 2 1/2" diameters to 5"-10" diameters. Foam pumper capacity has gone from 1,000 gpm to 2,500-6,000 gpm. Importantly, storage tanks for flammable and combustible liquids have increased in size dramatically from 125-150 feet diameter to 300-345 feet diameters.

Fire fighting procedures in the last eighteen years have also changed. A popular historic approach to extinguish a tank fire containing combustible or flammable liquid was to "surround and drown." Too often, however, the fire did not go out. The present inventor became one of the first in the field to recognize, through the review of numerous videos of tank fires, that foam, under the "surround and drown" system, was not reaching the full surface of the tank. The apparent reason was that the fire was "breathing", and in particular, there was an area, which came to be labeled the sweet spot, where the fire was taking in air (oxygen). Adjacent this sweet spot the fire would pulsatingly flame. A combination of sweet spot, breathing and thermal drafts was driving foam back and away from the middle of the tank surface.

Experience showed that the sweet spot typically lay just off of the center of the tank, and extending upwind approximately to the tank wall. For a variety of considerations, fire fighting nozzles are also upwind of the tank. The present inventor lead the field in revising techniques so that foam came to be applied predominantly toward the sweet spot.

For every tank size N.F.P.A. specifies a minimum "application density rate." Multiplying the square foot surface of a tank times the minimum "application density rate" yields a required minimum number of gallons per minute of foam that is to be applied. N.F.P.A. also specifies a minimum application time, e.g. 65 minutes. Applying the minimum g.p.m. foam for the minimum time should extinguish a tank fire. It became the present inventor's further experience, however, that applying a minimum gpm for the minimum time did not always lead to the extinction of a tank fire, even with foam applied predominantly to a sweet spot.

The above discovery led to the present invention. The inventor can demonstrate to the industry, in contrast to conventional wisdom, that each nozzle lays down a distinct footprint of foam. Conventional wisdom only considered it significant to measure a nozzle's maximum reach. The present inventor also teaches that foam has a "maximum run" on the top of flaming fluid. Maximum run is determined empirically to be approximately 100 feet. Putting together the above two discoveries, it can be demonstrated that if predicted footprints of foam require foam to "run" over 100 feet to completely cover a tank surface then notwithstanding applying a minimum, or even well over a minimum, "gallons per minute", and regardless of directing a significant amount of foam to the sweet spot, there will be areas of the tank that will not receive foam and there is some likelihood the fire will not go out.

As a result of the above discoveries, the present inventor teaches a method for configuring nozzles at a

burning tank such that they not only satisfy the minimum application density rate prescribed by N.F.P.A. and cover the sweet spot, but they also provide, taking footprints and foam run limitations into account, a foam run to all of the walls of the tank. To so configure nozzles, the inventor empirically determines a footprint for each size of nozzle potentially usable.

The inventor's method can be used in designing for a fixed placement of nozzles in a dike system, permanently installed surrounding a tank, and/or for staging mobil nozzles around a burning tank.

Tank fires involving in particular crude and high vapor pressure flammable liquids may present special extinguishing problems beyond those discussed above. Though foam is applied in a footprint such that the liquid surface is covered by foam run to all sides of the tank; and though a prescribed minimum density of foam is applied for a minimum application time; a fire in a tank of in particular crude or high vapor pressure flammable liquid may yet not be extinguished. Experience indicates that even though a relatively thick layer of foam covers the liquid surface extending to the tank walls, the heat of a tank wall may cause in particular crude or high vapor pressure flammable liquid to boil. This boiling or vaporizing of the liquid at the tank wall can prevent the foam in place from extinguishing the fire.

The present inventor has developed an improved fire extinguishing system that promises even more effective treatment of tank fires, especially those involving crude and high vapor pressure flammable liquids, than application of a footprint system alone. The improved system includes, in addition to applying foam to the liquid surface having a footprint such that foam run covers the surface to the wall, the further step of applying a cooling fluid, such as water, against portions of the exterior tank wall, in particular at a height at and/or slightly above the liquid level, to cool the tank wall.

Under the improved system, when managing resources at a fire, and in particular when managing available water pressure, resources should first be deployed to establish a foam footprint such that foam run covers the liquid surface. (Note: Footprint is used here in the singular for convenience. It should be understood that "footprint" may refer to a plurality of footprints, established from plural sources.) Furthermore, cooling the upper tank wall prior to a foam attack could be a waste of resources, or even counter productive, because cooling the upper wall may cause the steel to draw and curl inward. A curling inward of the top of the wall could complicate the process of establishing foam coverage. To the extent fluid resources or water is available after establishing the foam attack, including most particularly water pressure, a portion of the tank wall should be cooled at and slightly above the liquid level. The cooling is advantageously begun at the side of the tank wall having the longest foam run. Alternatively, a backside portion of the tank wall, the backside being the downwind side, is best cooled first. Preferably, a full circumferential portion of the tank wall is cooled, extending from the liquid level height up approximately 3 feet. Oscillating monitors stationed around a tank can be located to have the requisite throw to cover the circumference of the tank wall, resources permitting.

A further strategy in cost-effectively extinguishing tank fires, and in particular crude and high vapor pressure flammable liquid tank fires, includes positioning a dry powder nozzle over a tank sidewall portion. Preferably, the nozzle would be positioned over a front portion of the tank wall, the front being the upwind side. A preferred nozzle would include both foam and dry powder capacity. The nozzle would be remotely controlled.

In specific parts of the country, primarily urban areas where concentrations of ozone in the summer or carbon monoxide in the winter exceed established air-quality

standards, the Clean Air Act Amendments of 1990 mandate compounds that add oxygen (referred to as oxygenates) be added either seasonally or year round to gasoline. Such oxygenates increase the octane of the gasoline and improve air quality.

Even though oxygenates are mandated primarily in urban areas, it is estimated that oxygenates are added to more than 30 percent of the gasoline sold in the United States presently. By the end of this decade, the Oxygenated Fuels Association estimates that oxygenates will be added to 70 percent of the gasoline sold in this country.

Methyl tertiary butyl ether (MTBE) comprises one popular oxygenate permitted in unleaded gasoline up to a level of 15 percent. MTBE is a volatile organic compound (VOC) made from methanol and derived from natural gas. As one of the primary ingredients in reformulated gasolines, production of MTBE in 1993 ranked second among all organic chemicals manufactured. In 1993, 24 billion pounds of MTBE, worth about $3 billion, were produced. MTBE is commonly used because of its low cost, ease of production, and favorable transfer and blending characteristics.

Although MTBE comprises a popular, cost effective clean-burning oxygenate, with high octane and "relatively low" volatility, the U.S. Environmental Protection Agency (EPA) has tentatively classified the substance as a possible human carcinogen. Hence, other oxygenates, such as TAME (tertiary amyl methyl ether) are receiving serious development and consideration. Ethanol and ETBE (ethyl tertiary butyl ether) may compete for the consumer market. Environmental, health, economic and even political factors will probably affect the success and market share of competing products in this area of "finished product" hydrocarbons, gas additives and/or blended fuels.

As of this date, MTBE is representative of a growing inventory of "finished product" fluids that are manufactured in such quantities as to require storage in large tanks and that have either a relatively low boiling

point (as compared to gasoline or crude, for instance) or a low auto-ignition temperature, or possibly both. The boiling point of MTBE is approximately 133°F. MTBE's auto-ignition temperature is approximately 450°F. The auto-ignition temperature of gasoline, by comparison, is approximately 900°F.

The increased production of and need for "finished product" hydrocarbons - blended fuels, MTBE, TAME and the like - increases the danger and risks of handling fires involving such fluids. Produced and consumed in large volumes, the fluids must be stored in large tanks. The present inventors have discovered that existing systems for extinguishing hydrocarbon tank fires, including systems for the management of foam attack, should be improved to cover the difficult and dangerous situations that could arise with MTBE and the like tank fires.

The present invention discloses improved fire fighting systems with steps that are beneficial when addressing fires of low boiling point and/or a low auto-ignition point fluids. The invention includes steps for improving foam attack techniques. The present invention also teaches incorporating improved steps and improved foam attacks into systems using nozzles stored on or around a tank rim as well as distant from the tank.

SUMMARY OF THE INVENTION

A method is disclosed for assisting in extinguishing flammable and combustible liquid tank fires using foam. Footprints for a plurality of potentially configured nozzles are empirically determined through shooting foam from the nozzles onto a grid. Nozzles are then configured around a tank such that predicted footprint, adjusted for the height of liquid in the tank, will cover a tank surface with foam under the limitations of maximum foam run.

An improved method is also disclosed for extinguishing tank fires including crude and high vapor pressure flammable liquid tank fires. This method includes applying foam to a liquid surface in a tank with a footprint such

that foam run covers the liquid surface, and applying cooling fluid against at least a portion of the exterior tank wall at a height at and/or slightly above the liquid level, to cool the tank wall. In the absence of the ability or the resources to apply fluid to cool a full circumferential portion of the tank wall, or prior to when such resources can be fully in place, preferred embodiments include first applying fluid against a portion of the tank wall having the longest foam run. Alternatively, preferred embodiments include first applying fluid against a backside portion of the tank wall. Three feet has been found to be an approximate advantageous height above the liquid level at which to apply the cooling fluid. Oscillating monitors can be advantageously staged around the tank to throw water on the requisite portions of the tank wall. In some cases it is also advantageous to position a dry powder nozzle, or a foam and dry powder nozzle combination, above a tank side wall. A frontside portion of the tank wall would preferably be selected. The nozzle can be remotely positioned and operated through use of an extendable platform or boom.

A fire fighting technique is disclosed for industrial scale tanks that combines a foam attack with a cooling attack on inner and outer tank wall portions. The cooling attack is directed preferably at a level that is approximately that of the height of the residual fluids in the tank. The cooling attack is preferably conducted subsequent to establishing the foam blanket. Such a system proposes to minimize fire extinguishing time and to conserve foam, costs and human resources.

Preferably, portions of the outer tank wall would be cooled with water while portions of the inner tank wall would be cooled with foam. The nozzles for cooling tank wall portions may, in some cases, be the same as the master stream nozzles used to perform the foam attack. Alternately, such nozzles may be additional nozzles staged a distance from the tank. Nozzles located on the rim of

the tank might also be used, either permanent nozzles or temporarily placed nozzles such as a wand nozzle. Aerial nozzles positioned above the wall of the tank might also be advantageously used. Preferably, one or two aerial nozzles would have the capacity to throw dry chemicals.

The foam attack to establish the foam blanket could be accomplished through bubbling foam up through the tank or through discharging foam down the inside walls of the tank, as well as by staged nozzles distant from the tank. The choice is largely dictated by the circumstances.

One aspect of the invention, for foam attacks that include empirically determining a footprint for a nozzle and configuring one or more nozzles such that predicted footprint and predicted foam run cover a tank fluid surface, includes creating a footprint of foam outside of the tank with a nozzle to be utilized in extinguishing the fire. Aspects of the foam footprint, such as range, footprint length and footprint width, can be noted and advantageously used to more precisely configure the nozzle or nozzles to achieve an effective and efficient foam blanket.

In another aspect of the invention, also including a foam attack that empirically determines a footprint for a nozzle and configures one or more nozzles such that predicted footprint and predicted foam run cover a tank fluid surface, at least one of predicted footprint or predicted foam run is adjusted to take into account at least one further factor. These further factors may include the selected nozzle stream width, the selected and percent of foam concentrate, as well as actual wind conditions, actual head pressure, actual burning fluid, actual type of foam being utilized and the estimated temperature of the burning fluid. Some variations in footprint range, footprint width, footprint length and foam run can be precalculated based upon a variation in the above factors. In particular, variations in footprint range can be precalculated based on variations in water

head pressure. Variations in foam run can be precalculated based on variations in foam type, percent concentration of foam and type of fluid burning.

BRIEF DESCRIPTION OF THE DRAWINGS

A better understanding of the present invention can be obtained from the detailed description of exemplary embodiments set forth below, to be considered in conjunction with the attached drawings, in which:

Figure 1A illustrates an empirical technique for predicting a footprint for a given nozzle and certain nominally selected conditions.

Figure 1B illustrates a variation in footprint length and footprint width for various sized nozzles, from 2,000 gallons per minute to 12,000 gallons per minute.

Figures 2A-2T illustrate the use of predicted footprints together with predicted foam run to stage one or more nozzles in order to achieve coverage of the liquid surface in a tank with foam.

Figure 3A illustrates tank wall cooling for an outer tank wall surface.

Figure 3B illustrates a foam attack wherein a foam blanket is achieved using a footprint plus predicted foam run.

Figure 3C illustrates outer tank wall rim cooling as well as the utilization of a staged nozzle over the edge of the tank that might preferably provide dry powder capability.

Figure 4A illustrates a foam attack achieving a foam blanket through bubbling foam up from the bottom of the tank. Figure 4B illustrates a foam attack achieving a foam blanket using either fixed or temporary rim mounted foam nozzles.

Figure 5A illustrates outer wall cooling using distantly staged nozzles, permanent and temporary rim mounted nozzles and/or an aerial nozzle.

Figure 5B illustrates inner tank wall rim cooling utilizing a distantly staged nozzle, an aerial nozzle and/or rim mounted nozzles, either permanent or temporary.

Figure 6 illustrates throwing a nozzle footprint adjacent the tank on fire.

Figures 7A and 7B are tables showing a variation in range of a nozzle of a given size and for a given expansion, based on variations in water pressure.

Figures 8A through 8E illustrate a method for extinguishing fire utilizing blanketing nozzles and interior rim cooling nozzles.

Figures 9A through 9F give and illustrate variations in foam expansion, 25% drain time, control time and extinguishment time for two types of foam at two concentrations.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

Each fire fighting nozzle, it has been discovered, and the present invention teaches, will lay down a characteristic footprint of foam in standard operation. Although flammable and combustible liquid tanks vary in diameter, they share an approximate common height, 50 feet (45 feet to 70 feet). Nozzle footprint studies can be run assuming a supply of a standard minimum water pressure, usually 100 psi, but possibly up to 125 psi, with the nozzles pointed in a standard inclination to the horizon. Given standard pressure, a nozzle and a particular foam concentrate, metered at an appropriate level, will have associated with it a characteristic "throw footprints. This footprint can be measured empirically by shooting the nozzle toward a grid laid out above the ground in a tank at an appropriate distance away. The observed mark of the perimeter of the foam on the grid describes the nozzle's footprint. Theoretical adjustments can be made for an increase or decrease in footprint due to potential height of liquid in a tank.

Experience and study show in addition that a given foam will run a limited distance over flaming liquid. The

inventor empirically determines that maximum flow run for a foam.

Fire fighting nozzles are advantageously staged upwind of a burning tank. The sweet spot of the burning tank, that is the spot where the burning fluid appears to take in air, usually lies between the wall and the center of the tank in the upwind direction. Approximately 125 feet comprises a standard distance for configuring nozzles from a burning tank wall.

Each tank diameter has an application density rate prescribed by NFPA. Multiplication of the minimum application density rate times the square feet of surface area of the tank yields a minimum application rate of foam in gallons per minute.

The invention comprises a method for configuring nozzles from a tank such that their total gpm yields the minimum application gpm, their footprints tend to concentrate foam upon a predicted sweet spot of the tank while the combination of footprints does not require foam to run greater than an empirically estimated maximum foam run for the particular foam used.

Figures 1A and 1B relate to the empirical method for determining the footprint of a nozzle. As illustrated in Figure 1A, nozzle 10 is a standard distance 16 from an empty tank 32. Individuals 34 stand in the bottom of the empty tank. A grid of lines 12 are stretched across the top of the tank each line bearing flags 13. The lines may be stretched across the top of the tank laterally and longitudinally in approximately 10 foot intervals. Foam F is shot from nozzle 10. The individuals 34 on the ground in the tank observe the perimeter of the footprint 14 by observing which lines 12, more easily indicated by means of flags 13, are being touched by the perimeter of the foam as it passes through the rim 22 of tank 32.

Figure 1B illustrates empirically determined footprints 14, the general length 18 and breadth 20 indicated for different nozzles using a particular foam.

In the example of figures 2A through 2T the maximum foam run for the particular foam used was approximately 100 feet.

More particularly, Figure 2A illustrates a configuration for a 209 foot diameter tank 32. Three nozzles 10 are deployed and aimed. The nozzles are deployed distance 16 away from tank 22, which comprises a standard 125 feet. Footprints 14, empirically determined to be associated with particular 2,000 gpm nozzles 10, yield a concentration of foam around an estimated sweet spot area 26, more particularly defined by estimated boundary 30, while requiring a maximum foam run 24 of only 85 feet. It can be seen that a footprint of a 2,000 gpm nozzle has a general maximum breadth 20 of approximately 45 feet and a general maximum length 18 of approximately 90 feet.

Figure 2B shows the application of the same method to the same 209 foot diameter tank 32 utilizing one 6,000 gpm nozzle 10. Again, the nozzle is deployed a standard distance 16 of 125 feet from tank wall 22. Predicted sweet spot 26 receives a significant foam concentration and the maximum foam run required can be held to 75 feet.

Figures 2C through 2T provide examples similar to Figures 2A and 2B.

Figs. 3A through 3C illustrate an improved system for the extinguishing of tank fires including crude and high vapor pressure flammable liquid tank fires. In Fig. 3A, tank T is shown having liquid surface LS. Lines 41 bring a source of fluid, preferably water, to nozzles 42. Nozzles 42 are illustrated as staged approximately 75 ft. away from tank T. Nozzles 42 are preferably oscillating monitors that can distribute the fluid, such as water, by paths 43 against exterior wall portions of tank T. A height 40 is illustrated indicating a height above the liquid surface LS of the liquid in tank T to which the fluid should be applied. Preferably, height 40 is approximately 3 feet.

Fig. 3B illustrates a top view of tank T showing footprint F. Footprint F is the footprint generated by some source or sources of a foam fire-extinguishing medium. A single footprint is shown in Fig. 3B and discussed herein. As mentioned above, it should be understood that "footprint" F, here, could comprise a composite or multiplicity of footprints from a variety of sources of foam, such as illustrated in Figs. 2. Fig. 3B illustrates footprint F having a foam run 44 of 90 feet on two sides and a foam run 46 of 60 feet on two other sides. Common commercial foam today may be expected to have a foam run of up to 100 feet. Thus, footprint F would be expected to yield a foam run such that foam covers all of liquid surface LS and reaches all of the sides of tank T. In particular, if liquid in tank T comprises crude or high vapor pressure liquid, it is advisable (1) to apply foam in footprint F to liquid surface LS at the specified minimum gallons per minute for the minimum time; and (2) to apply in addition fluids such as water to cool portions of the walls of tank T. These portions would especially comprise a level around and slightly above the liquid surface LS level. An important portion of tank wall to cool first is the portion to which the foam has the longest run. In the illustration of Fig. 3B, the portion that might be most advantageously cooled first would be the portion in the direction 44 of foam run.

Fig. 3C illustrates further an improved method of extinguishing fire in a tank, including crude and high vapor pressure flammable liquid. Footprint F is illustrated as established on liquid surface LS in tank T by means of nozzle 48. (Again, a single footprint is illustrated for convenience.) Sources of additional fluid 42, such as oscillating nozzles, are illustrated staged around tank T such that they can throw additional fluid, such as water, along paths 43 against exterior side portions of the wall at a level at and slightly above the height of liquid surface LS. Foam from nozzle 48 is shown

having path 45. In addition to foam nozzle 48 and fluid nozzles 42, an additional dry powder nozzle 54 is shown in Fig. 3C, alternately staged in two positions. Dry powder nozzle 54 is shown stationed on platform 52 or boom 50. Dry powder nozzle 54 may also include foam capability. Dry powder nozzle 54 is advantageously staged on the frontside of the tank. (Again, the frontside of the tank refers to the upwind side of the tank while the backside of the tank refers to the downwind side of the tank.)

If the footprint of foam creates a relatively equal foam run around the sides of tank T, the sides of the tank that would preferably be cooled first, by the application of liquid to exterior wall portions of the tank, would be the backside portion of the tank wall. In Fig. 3C BS indicates the backside portion of the tank wall. FS indicates the frontside portion of the tank wall in the embodiment illustrated.

MTBE, as well as other "finished product" fluids and blended fuels, is stored in large tanks. Specifically, such tanks may have a height of 50 feet to 75 feet and a diameter of from 100 feet to several hundred feet. In the case of a fire in an MTBE tank, it has been discovered that it is relatively straightforward to achieve a "knock down" of the flames. However, vagrant ghost flames reappear across the surface of even an established foam blanket, and persist for quite a period of time after knockdown. ("Knock down" signals the extinguishment of the majority of the flame.) Particularly with MTBE (and it is anticipated to be true with other similar fluids, such as finished product fluids having a relatively low boiling point and/or a low auto-ignition temperature), such flames may persist after knock down for several hours, usually adjacent to and dancing from the inner walls of the tank.

Treating and containing these vagrant flames exhausts foam and other resources and significantly increases the expense of extinguishing the fire. Residual vagrant flames from an MTBE fire may persist for as long as three hours

after knock down. During such time a full foam blanket must be maintained. The possibility of lessening that considerable expense heightens the value of the system of the present invention, which teaches a cooling attack on portions of the tank walls, and in particular, inner portions of the tank walls.

Absent the new technique, a foam blanket must be maintained until the mass of the tank cools essentially below the boiling point of the fluid. Up to that point a fire fighter must guard against boiling fluid wicking at or near the wall, and the fluid behaving somewhat like a flammable gas. The depth of the foam blanket appears of little relevance in these circumstances, until the tank walls can be sufficiently cooled.

Foam attacks can achieve a foam blanket and maintain a foam blanket with a variety of techniques. Figures 1A, 1B and Figures 2A through 2T illustrate one method of foam attack using nozzles staged distant from the tank.

Figure 1A illustrates one process for empirically determining a nozzle footprint. Figure 1B illustrates a variety of footprints including footprint length and footprint width for a variety of sizes of a particular type of nozzle. This information is typically gathered under a set of nominal conditions such as a nominal 100 psi water pressure, nominal wind conditions of 5 to 10 miles per hour, nominal metering of foam concentrate and an optimal straight stream nozzle pattern.

Figures 2A through 2T illustrate how such empirical footprint information can be used to stage one or more nozzles from a tank such that predicted footprint and predicted foam run will cover the surface of the fluid in the tank with foam. As foam blanket should be achieved having the requisite density.

Maximum foam run is generally precalculated based upon the type of foam, and the metering or concentration of the foam. The present inventors believe that heretofore not only has foam run for the newer environmental friendly foam

concentrates not been calculated, but that variations in foam run caused by the volatility and surface tension of the fluid burning as well as the temperature of the fluid burning have also not been taken into account. Whereas, prior foam has generally been thought to run at least 100 feet, under certain circumstances, such as those mentioned above, the maximum foam run may only be 60 to 70 feet.

Figures 4A and 4B illustrate to alternate techniques for mounting a foam attack and achieving and maintaining a foam blanket. Figure 4A illustrates nozzles attached to tank T. The nozzles are connected by lines L to sources of foam SFM. Foam from nozzles N percolates up through fluid FLD and creates a foam blanket FM on the surface of fluid FLD in tank T. The foam blanket, as it is achieved, should help to at least knock down flames FL.

In Figure 4B nozzles N are staged on the rim of tank T. The left hand nozzle illustrates a fixed nozzle. The right hand nozzle is drawn to illustrate a temporary wand type nozzle. Foam FM from nozzles N is discharged down the side of the walls of tank T. If such nozzles are staged at appropriate distances around the periphery of the walls of tank T a foam blanket can be achieved over fluid FLD in tank T covering the surface of the fluid in the tank and at least knocking down the flame FL of the burning fluid. Again nozzles N are connected by lines L to sources of foam SFM.

To effectively and expeditiously extinguish MTBE and the like fires, the present invention teaches a system of tank wall cooling, inner and outer, in addition to an improved foam attack, and preferably combining the tank wall cooling with an additional selective dry chemical capability. The system forms a variation on and an improvement of the teaching of the two above referenced pending patent applications, (and incorporated herein by reference.)

In many cases it is anticipated that tank wall cooling will be performed by equipment assembled and staged outside

of the tank. Alternately, however, fixed systems can be used to the extent they are in place. The system can be practiced with either fixed or mobile nozzles staged a distance from, or upon, or over, the tank walls.

Figures 3A through 3C illustrate the technique of outer tank wall cooling. Figure 3A illustrates the use of nozzles 42 staged approximately 75 feet from the wall of a tank. The nozzles discharge a fluid 43 that is probably water. Preferably, the fluid is discharged at a portion of the outer tank wall at approximately the height of the fluid resident and the tank. LS indicates the liquid surface level in tank T of Figure 3A. The water illustrated as striking the tank wall at point 40 spreads and cools at least some outer surface portion of the tank wall, preferably in an annular ring around the tank at approximately the level or slightly above the level of the liquid surface LS of the resident fluid in the tank. Nozzles 42 are shown as supplied with their fluid through lines 41.

Figure 3B illustrates a footprint that could be used to mount a foam attack with nozzles staged distant from tank T. Footprint F is illustrated upon the surface LS of the liquid resident in tank T to be of such dimensions that footprint F together with at least a 90 foot foam run should cover the surface LS of the resident fluid with a foam blanket. Direction 44 illustrates the area of maximum foam run for the footprint. Direction 46 illustrates the area of minimum foam run required for the footprint.

Figure 3C illustrates mounting both the foam attack and an outer wall cooling attack upon tank T at the same time. In addition, aerial nozzle 54 is illustrated staged over the wall of tank T. In practice, aerial nozzles would be staged on opposite sides of the tank, to the extent possible. Preferably, aerial nozzle 54 would have dry chemical capability. Nozzle 48 is illustrated as discharging foam onto liquid surface LS of the fluid in tank T. Nozzles 42 are illustrated as discharging fluid

43, probably water, onto outer tank walls surfaces of tank T at or about the level of the resident fluid in the tank.

The walls of a tank that have experienced a full surface fire are slow to cool below the boiling point of a low boiling point fluid, such as MTBE (131°F), or any other similar low boiling point fluid. It has been discovered in particular that the inside surface of a wall will be slow to cool, even after the outside surface of the wall is cooled, and even though the fluid is relatively cool below the surface of the fluid in the tank. (Not far below the surface of a resident fluid, even a surface that is or was recently on fire, fluid temperature can remain relatively cool due to the heat transfer associated with the process of vaporization.)

Since inside the tank the fluid is in thermal communication with tank wall surfaces, the present invention teaches that a specific attack cooling tank wall portions at or about the level of the surface of the resident fluid, and in particular inside tank wall portions in such areas, will significantly reduce the period of time that must otherwise be consumed containing and guarding against vagrant ghost flames from igniting fluid vapors. There is expected to be an equivalent benefit from cooling tank wall surfaces, especially inside surfaces, when the resident fluids have a low auto ignition temperature, again even if such fire can be knocked down relatively quickly.

The outer tank wall can be cooled effectively with water. Although portions of the inner tank wall could be cooled with water, foam is preferable. Water inside a tank sinks below lighter resident fluids. Such presents a risk of the water being raised by a heat wave to its boiling point and bubbling over, carrying with it any flaming contents above. The boiling up of underlying water, expelling burning fluids above, has been known to occur in tanks of burning crude. Since this poses a significant risk, foam forms the preferred cooling medium for inner tank wall surfaces.

Master stream nozzles used for "knock down" of a fire can be utilized to subsequently cool inner tank wall portions, presuming that the tank diameter is such that opposite inside portions of the tank walls lie within the range of the nozzles. Preferably, two aerial nozzles would be staged over the tank walls. These aerial nozzles could apply both foam, useful for inner wall cooling, and selected dry chemicals to attack any small persistent flames at the fluid surface. It has been found that the dry chemical Monex or Purple K works well with ATC foam on MTBE fires, at least in tests on small scale. The present inventors anticipate that Purple K will work well in fires with most blended fuel fluids. Monex has, after several fire tests, proven to be somewhat more effective than Purple K. Monex is Purple K treated with urea. For ships and barges it is known to use cellar nozzles for foam and dry chemicals. A modification of such a cellar nozzle could be configured into a temporary wand to be hung over the side of a tank.

Figure 5A illustrates the use of a distantly staged nozzle NS, a temporary rim mounted nozzle wand NW, a permanently mounted rim nozzles NF and an aerial nozzle NA, all being used to cool portions of the tank wall of tank T. More particularly, the four nozzles are being utilized to cool outside portions of the wall of tank T. Aerial nozzles are particularly effective and should be used mainly on tank fires containing MTBE, octane booster fuels or the like for internal wall cooling. After knock down an aerial nozzle might also be used for a brief time for some outer wall cooling. Figure 5B illustrates the use of distantly staged nozzle NS, temporarily staged rim nozzle NW, permanently located rim nozzle NF and aerial nozzle NA in order to cool inside portions of the wall of tank T. Nozzle NS is only particularly effective if it can be located such that its range permits it to through foam against the far inside side wall portion of the tank at a height that is approximately the height of the resident

fluid in the tank. The fluid of preference to cool inside tank wall portions comprises foam. Aerial nozzle NA is situated most advantageously to cool inside tank wall portions. Rim nozzles can be utilized to cool inside tank wall portions by discharging foam down the inside of the tank wall. It is preferable to cool an annular ring around the inside tank wall at or about the height of the resident fluid. For this reason, a plurality of nozzles should be required to achieve the cooling of the full annular ring with foam.

The present inventors have also determined that the establishment and the maintenance of the proper foam blanket can be critical in extinguishing tank fires. The more difficult the fire to extinguish, the more sensitive the residual fluid, the more critical becomes the establishment and maintenance of a proper foam blanket. Thus, an improved system for foam attack can be important in conserving resources, such as foam, as well as in extinguishing the fire as expeditiously as possible.

To insure the efficient maintenance of a proper foam blanket on the surface of the fluid, the present inventors have discovered that predicted footprint and/or predicted foam run can be effectively adjusted by taking into account one or more of several factors inherent in the actual circumstances. One factor may be the actual variance of the nozzle footprint at the site from a predicted nozzle footprint under the circumstances.

It is advantageous to establish nominal footprints for various nozzles based on nominal conditions, such as nominal wind condition (5 to 10 miles per hour), nominal pressure (100 psi), nominal foam concentrate meterings (3%, 6%, 9%), etc. Such empirically determined nominal footprint information, together with predicted foam run, can be utilized to make a first estimate of the equipment and resources necessary to establish and maintain a successful foam attack. The footprint system has been disclosed in the above referenced pending application.

The present inventors have now discovered that it can be advantageous, at the scene of the fire, to take into account several actual conditions. As mentioned above, it can be advantageous to throw an actual nozzle footprint upon some nearby observable surface adjacent the tank fire. The footprint actually thrown by the nozzle under the selected metering and nozzle stream width, and with the given wind and head pressure and nozzle stream width, is noted, and several aspects of the footprint might be measured. These aspects include footprint width, footprint length and footprint range (distance from nozzle to toe of footprint). The configuring of the nozzle or nozzles might be adjusted and improved to take into account significant variations between observed nozzle footprint, under actual conditions, and predicted nozzle footprint and/or predicted foam run.

Figure 6 illustrates a technique that can be utilized to perfect and improve the foam attack using a nozzle staged a distance from the tank. Although, as illustrated in Figures 1 and 2, the firefighter preferably has available a predicted footprint for given nozzle under nominal conditions, variations of the actual footprint to be thrown by a given nozzle under actual firefighting conditions may be important. For that reason, the present inventors teach throwing an actual footprint away from or outside of the fire, preferably on an area just adjacent the tank, in order to keep wind conditions more or less constant. Various aspects of this footprint can be noted, including its range, the footprint length and the footprint width. Staging or configuring the nozzles then to be used to fight the fire can be adjusted to take into account variations of the actual footprint from the predicted footprint. Figure 6 illustrates nozzle N, supplied with foam by line L, throwing a footprint adjacent tank T, tank T being engulfed with flames FL. The footprint has footprint range FPR, footprint length FPL and footprint width FPW.

Foam attacks for extinguishing a tank fire are frequently mounted using nozzles staged outside of and peripheral to the tank on fire. Such type of foam attacks are discussed in the above-referenced pending patent applications. The attack may include empirically determining the footprint for a nozzle and configuring one or more nozzles such that predicted footprint and predicted foam run cover a tank fluid's surface.

Several additional factors can be taken into account, and in certain circumstances should be taken into account, in order to perfect and enhance the efficiency of the foam attack. It is important to blanket the full surface of the fluid in the tank. However, at the same time it is important to efficiently utilize resources, including in particular the expensive resource of foam.

It is one aspect of the present invention that the type of fluid burning, and in particular the fluid volatility and/or surface tension, affects foam run. When the surface tension of the burning fluid is low, for instance, it is has been discovered that the fluid does not support a significant run of film from the foam. Film from the foam can be quite helpful in extinguishing tank fires. When the film is not supported by the surface tension of the fluid, the fire must be extinguished by the bubbles of the foam. Foam bubbles do not run as far as foam film.

Furthermore, it has been discovered that the volatility of the fluid on fire can affect the capacity of a foam to run. Reasons can be proposed for this effect, although the process is probably complex.

The level of concentration, or the selected metering, of the foam used (usually between standard metering percents of 3%, 6% and/or 9%) can also affect foam run. In general, the greater the percent or concentration of foam, the slower the foam to run. However, the type of foam also enters into the calculations. Newer, more environmentally friendly compositions have been found to run at 6% concentration much like older foam compositions ran at 3%.

It is advantageous to have experimented with, and be advised by precalculations, of the capacity of different types of foam to run when utilized in different percent concentrations. Furthermore, the same foam that should run up to 100 feet on crude or gasoline, may only run 60 to 70 feet on an MTBE fire. Footprint range, footprint length and footprint width can be affected by the water pressure or head pressure, by wind conditions and by the stream width. Figures 7-A and 7-B illustrate the change in footprint range, (that is the distance from the nozzle to the footprint toe furthest away from the nozzle) for different nozzles as water pressure, measured in pounds per square inch, varies. 100 psi comprises nominal pressure. Footprint calculations may be made assuming that a nozzle will be supplied with 100 psi. In point of fact, under actual conditions, the head pressure or psi of water supplied may vary by 25 psi or so either way around the nominal 100 psi. Figures 7-A and 7-B, calculated for two different foam expansion ratios, illustrate how nozzles with a gpm volume of from 2,000 gpm to 14,000 gpm vary their range depending upon variations in pressure. Experience has shown that pressure affects not only footprint range but also footprint length and to a small extent footprint width. The greater the pressure not only the greater the range but also the greater the footprint length. Footprint width also expands to a small extent with increased pressure. Concomitantly, as pressure decreases, range decreases, footprint length decreases and, to a small extent, so does footprint width.

Nozzles for extinguishing a tank fire are, for at least a variety of reasons, staged upwind of the fire. Most calculations assume a nominal wind of 5 to 10 miles per hour. Experience has shown, however, that with winds of 20 mph or greater range calculations should generally be increased by approximately 10%. Winds of 20 mph or greater also lengthen the footprint somewhat, experience has shown.

The footprint width should be anticipated to narrow to some extent with winds greater than 20 mph.

Most fire fighting nozzles used for extinguishing tank fires contain an adjustable sleeve that slides over the main barrel of the nozzle. When the sleeve is in its full extended position, the nozzle is directed to throw its most narrow and focused stream. When the sleeve is in its most contracted position with respect to the basic nozzle barrel, the nozzle is set to throw its broadest, most fog-like pattern. Generally, fog patterns are used to protect personnel and equipment. The optimum stream width for a fire fighting nozzle attempting to throw a maximum distance a suitable footprint of foam is what is referred to as the "straight stream" pattern. The straight stream pattern appears tube-like emerging from the nozzle. It does not spread immediately into a fog pattern. Alternately, it does not exhibit a focused or hour-glass type shape, narrowing to a focal point slightly downstream of the nozzle. A straight stream is the preferred throw pattern because it is believed to maximize the reach of the nozzle and the nozzle's foam quality, enhancing foam expansion and drainage qualities.

Notwithstanding the above, the sleeve setting and thus the stream width may be altered from the straight stream pattern under certain circumstances in fighting a fire. For instance, the setting of the sleeve, and thus the stream width, has somewhat of an effect upon the expansion of the foam. To achieve a slightly different expansion the sleeve and the stream width might be altered. Also, the stream width affects range. The sleeve width might be altered to intentionally reduce range. When the stream width is widened, range is reduced, the footprint length is reduced and the footprint width is increased.

Foam expansion is determined by the aeration of the nozzle. Some nozzles permit settings that vary the aeration. Other nozzles are built to achieve a particular aeration ratio. Aeration affects foam expansion. Figures

7-A and 7-B show the variation in range with water pressure for a variety of nozzles at two different expansion ratios. It can be seen that the low 3.1 expansion results in significantly greater range for the nozzle. In most circumstances, thus a lower expansion such as a three-to-one expansion is desired.

In operation, a foam attack is designed and carried out using the best available equipment and facilities. The foam blanket may be established using fixed rim nozzles, temporary rim nozzles, staged distant nozzles and/or any aerial nozzles that may be brought to bear over the rim of the tank. Assuming that one or more staged distant nozzles will be used, the firefighter is best provided with predicted footprints for that nozzle size at least under nominal conditions. Based upon such information the firefighter configures one or more nozzles such that predicted footprint and predicted foam run will achieve the requisite foam blanket over the surface of the liquid in the tank.

If possible, the firefighter throws a sample footprint adjacent the tank away from the fire. Variations in range length and/or width of such footprint from the predicted footprint are noted. The configuring of the one or more nozzles should then adjusted accordingly to take into account variations of predicted footprint under actual conditions. For instance, range can be varied by varying the inclination of the nozzle stream. Range can be shortened by increasing stream width through use of an adjustable sleeve on the nozzle. Foam run can be recalculated based upon the foam being utilized, the selected metering or concentration of foam, as well as the actual fluid on fire including its volatility and surface tension, as well as its estimated temperature of burning.

One or two aerial nozzles will be staged over the rim of the tank if possible, providing at least dry chemical capability. Preferably, the nozzles provide both foam and dry chemical capability.

After a foam blanket has been established outer and/or inner tank wall cooling may be commenced. For low boiling point and/or low auto ignition fires, inner rim cooling with foam is preferred. The rim cooling must be provided by whatever nozzles are available.

Outer rim cooling may also be provided or may alternately be provided. Outer rim cooling is usually accomplished using water. Tank wall cooling is preferably performed at or about the level of the resident fluid in the tank.

Configuring of staged nozzles for a foam attack can also be varied depending upon actual footprint and the actual foam run expected taking into account various actual factors. Actual footprint can be more closely predicted based on variations of water pressure from nominal as well as variations in the selected metering of the foam, the type of foam and the stream width selected. Estimations of foam run can be adjusted in accordance with the type of fluid burning, and in particular its volatility and surface tension, as well as its temperature of burning. The particular type of foam and its concentration will also be a factor in estimating actual foam run.

MTBE	
Boiling Point	**131°F (55°C)**
Specific Gravity (Water = 1.0)	**0.74 @ 68°F (20°C)**
Solubility in Water	**Moderate, 4.8% wt. @ 68°F (20°C)**
Vapor Density (Air - 1.0)	**3.1**
Vapor Pressure	**Reid 8 PSIA @ 100°F (38°C)**
Flash Point	**-30°F (-34°C) (Tagged Closed**
Auto Ignition Temperature	**Cup)**
Flammable Limits in Air	**435°F (224°C) AIHA[11]**
Surface Tension	**(% by Volume) 2.5-15.1**
	<17 dynes/cm

The above table gives significant statistics for MTBE, a paradigmatic high octane fuel. It is believed that the three largest factors that affect firefighting efforts, of

those listed above, are the low boiling point (131°F/55°C), the solubility in water (moderate, 4.8% wt. @ 68°F/20°C), and the surface tension (<17 dynes/cm). Observations regarding each of these three issues will be addressed in further detail below.

Boiling Point (131°F/55°C)

With a low boiling point (in comparison to the many of the other hydrocarbon liquids), fires involving MTBE stubbornly persist along the inner tank wall, notwithstanding the firefighters having successfully established a foam blanket. The tank wall temperature easily exceeds the boiling point of the MTBE (131°F/55°C), as is evident by the difficulty to extinguish the rim after knockdown. One can view the MTBE physically boiling through the foam blanket. The foam blanket is inhibited from reaching the tank wall itself.

One procedure is to practice exterior wall or rim cooling, usually through the use of water via fixed or portable monitors. With ordinary fuels one would continue to apply exterior rim cooling to the tank until the water no longer flashes to steam, indicating a suitable cool shell. However, with MTBE rim cooling (and continued foam application) must be continued until the inner tank wall temperature is reduced to below MTBE's boiling point, 131°F, 55°C, some 81°F/45°C cooler than the point at which the water no longer flashes off of the side of the tank. Simple visual aids do not work. In an experiment with a MTBE fire in a 30 foot tank, exterior rim cooling took 2 1/2 hours to reduce the temperature of the inner steel tank wall from ~500°F (auto ignition temperature) to ~130°F (boiling point).

Solubility in Water (Moderate, 4.8% wt. @ 68°F/20°C)

The fact that MTBE is only slightly soluble (4.8% wt. @ 68°F/20°C) actually impedes the effectiveness of the multipurpose synthetic foam blankets. The bonding of methanol and isobutylene produces the new product MTBE, which is a chemical and cannot be distilled into its

original components. Multipurpose foams are effective on methanol and the polymeric membrane will fall out of suspension and form an effective barrier impeding the mixing of the water in the foam with the methanol. With the newly produced chemical, MTBE, however, the polymeric barrier is non existent.

Indications are that the polymer in the foam blanket at least produces a more resilient bubble when applied to the surface of the burning MTBE and may inhibit the vapor from permeating through the foam blanket. It is also indicated that, by increasing the percent of concentrate in the water stream, the bubble becomes even more resistant to vapor permeation. Being only 4% soluble, it is possible to saturate MTBE with water. Unfortunately this saturation offers little consolation to the fire fighter. The burning characteristics change little, if any, once the MTBE is saturated.

Surface Tension (<17 dynes/cm)

Surface tension of MTBE (<17 dynes/cm) is very low in comparison to other hydrocarbons (gasoline $\geq$ 22 dynes/cm). This low surface tension eliminates the ability for AFFF's to form a film. Film formation is based on three factors: the surface tension of the fuel; the surface tension of the AFFF (17 dynes/cm); and the interfacial tension between the two. Film formation will only occur if the sum of the surface tension of the AFFF, and the interfacial tension between the two liquids are less than the fuel itself.

Gasoline fires, we now see, are forgiving. The new fuels, such as high octane boosters, including MTBE, are not forgiving. Greater control and a more elaborate strategy is required.

Figures 8A through 8C illustrate the beginning typical scenario in fighting a tank fire of a fluid like a high octane booster.

Figure 8A assumes that the appropriate foam attack has been determined, given the equipment, water, chemicals and environmental conditions. Blanketing nozzles BN are shown

staged. Their throw should land a footprint of foam that together with the foam run should establish a foam blanket upon the surface of the burning fluid in tank T. Figure 8B illustrates the footprints F of foam predicted to be thrown upon the surface of the fluid in tank T. The arrows indicate the predicted run of the foam from the footprint landed on the fluid surface. Flames FL in Figure 8B indicate the residual flames that will persist along the tank wall rim although the majority of the fire, illustrated by flames FL in Figure 8A, will be "knocked down" with the establishment of the foam blanket, illustrated as foam blanket FM in Figure 8C. A residual flame FL that persists along the tank wall or rim portions is again illustrated in Figure 8C.

It is believed that if and when the inner tank wall is cooled sufficiently, foam blanket FM will close with the inside of the tank wall and residual flames FL will be extinguished. Sufficiently cooling the inner tank wall such that residual rim flames disappear can be a long and arduous process. High octane fuels have low-boiling points. Until all flames are extinguished, the foam blanket must be maintained. Maintaining a foam blanket runs a high cost in the use of foam resources.

If an aerial is available, such that a dry-powder nozzle can be staged, preferably two, over rim portions of the tank, it may be possible to speed the extinguishment of the residual flames around the inner wall of the tank with a selective application of dry powder, once the fire is knocked down and a foam blanket established. Optionally, a dry powder and foam nozzle would be staged on the aerial. Regrettably, in many situations an aerial is not available.

Figure 8D illustrates preferred inner rim cooling using staged nozzles, or monitors, designated "RN" for rim nozzles. These nozzles RN may be of lesser size and power than the nozzles BN used to establish and maintain the foam blanket. Nozzles RN may comprise oscillating nozzles that have been used for exterior rim cooling. Nozzles RN may be

run off of auxiliary react lines. Once blanketing nozzles BN have established a foam blanket and knocked down the majority of the fire, nozzles RN may be staged as close as 80-100 feet to the tank walls. Blanketing nozzles usually must be staged 125-150 feet away. Rim nozzles RN are most advantageously staged from between 45 degrees to 100 degrees to the right and/or to the left of the blanketing nozzles, as illustrated in Figure 8D. Preferably two nozzles are used.

As illustrated in Figure 8E, blanketing nozzles BN are staged upwind of tank T. The combination of the velocity from the throw of the foam together with the wind tends to push foam blanket FM toward the farther edge of the tank FE. With the continued application and maintenance of the foam blanket, fresh foam thus tends to move toward portions of the far edge of the tank wall. Fresh foam carries water useful for cooling the inner tank wall. The most advantageous use for rim nozzles RN is to direct foam toward the leading edge LE or near edge of the tank to the blanketing nozzle. Experience has shown that the leading edge of the tank wall is the most difficult edge to reach with fresh foam. Preferably the throw of foam from rim nozzles RN should be such that the throw of the foam plus foam run would land and/or run (land/run) foam on the inside of, or at least proximate to the inside of, the leading edge LE of the tank wall.

In regard to choice of foam, Figures 9A through 9F give a variation in foam expansion, 25% drain time, control time, and extinguishment time for ATC foam and 3 x 3 foam, by comparison. Results are given for each foam in 3% and 6% concentrations.

The first priority is to knock down the full fire. Then the firefighter must extinguish residual flames and bring the inner tank wall temperature down to below the boiling point of the fluid. Selective application of dry powder, if available can be effective in extinguishing

residual flames. Contact with fresh foam with its high content of water is effective for inner rim cooling.

It is the time subsequent to establishing a foam blanket that is important to rim cooling. Rim cooling prior to establishing a foam blanket and knocking down the fire is not believed to be important, and could be counter productive if it caused the steel tank walls to draw and curl inward.

The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the size, shape, and materials, as well as in the details of the illustrated system may be made without departing from the spirit of the invention.

CLAIMS

What is claimed is:

1. A method for extinguishing tank fires, in particular crude, high vapor pressure flammable liquid, low boiling point and/or low auto-ignition point fluid, and the like, fires comprising:

establishing a foam blanket to cover a burning fluid surface in a tank; and subsequently

cooling inner tank wall portions.

2. A method for extinguishing tank fires, in particular crude, high vapor pressure flammable liquid, low boiling point and/or low auto-ignition point fluid, and the like, fires comprising:

establishing a foam blanket to cover a burning fluid surface in a tank; and subsequently

selectively applying dry powder to residual flames in the tank.

3. The method of claims 1 or 2 wherein establishing the foam blanket includes empirically determining a footprint for at least one nozzle; and

configuring one or more nozzles with respect to a tank such that predicted nozzle footprint and predicted foam run would cover a tank surface with foam.

4. The method of claims 1 or 2 that includes cooling outer tank wall portions at approximately the height of the fluid in the tank.

5. The method of claim 1 wherein the cooling comprises applying fresh foam to inner tank wall portions.

6. The method of claim 1 that includes selectively applying dry powder to residual flames in the tank subsequent to establishing a foam blanket.

7. The method of claims 2 or 6 wherein the selective applying is directed to portions adjacent a tank wall.

8. The method of claims 2 or 6 wherein the applying dry powder includes positioning a dry powder nozzle over a tank wall.

9. The method of claim 8 wherein the positioning includes positioning an aerial nozzle and/or positioning a wand nozzle.

10. The method of claim 6 wherein the applying dry powder is begun after the cooling is initiated.

11. In a foam attack system for extinguishing a tank fire that includes empirically determining a footprint for a nozzle and configuring one or more nozzles such that predicted footprint and predicted foam run cover a tank fluid surface, an improvement comprising:

creating a footprint of foam outside of the tank with a nozzle to be utilized in extinguishing the fire.

12. The method of claim 11 that includes:

measuring at least one aspect of the created footprint; and

taking into account the aspect when configuring the one or more nozzles.

13. In a foam attack for extinguishing a tank fire that includes empirically determining a footprint for a nozzle and configuring one or more nozzles such that predicted footprint and predicted foam run cover a tank fluid surface, an improvement comprising:

adjusting at least one of predicted footprint and predicted foam run to take into account at least one of the factors consisting of fluid height in the tank, wind conditions, nozzle stream width, head pressure, percent of foam concentrate, type of burning fluid, type of foam, and temperature of burning fluid.

14. The method of claim 13 that includes precalculating variations of at least one of footprint range, footprint width, footprint length and foam run based upon a variation of at least one of said factors.

15. The method of claim 14 wherein variations in footprint range are precalculated based on variations in pressure.

16. The method of claim 14 wherein variations in foam run are precalculated based on variations in at least one

of foam type, percent concentration of foam and type of fluid burning.

17. A method for extinguishing tank fires, in particular crude, high vapor pressure flammable liquid, low boiling point and/or low auto-ignition point fluid and the like, fires comprising

staging one or more blanketing nozzles to land one or more footprints of foam over a tank wall leading edge toward a central portion of the tank to establish, with foam run, a foam blanket over the surface of a burning fluid in the tank; and

staging at least one rim nozzle away from said blanketing nozzle such that said rim nozzle lands/runs foam within the tank proximate said leading edge.

18. The method of claim 17 wherein the staging a rim nozzle includes staging a rim nozzle between 45° to 100° to one side of a blanketing nozzle .

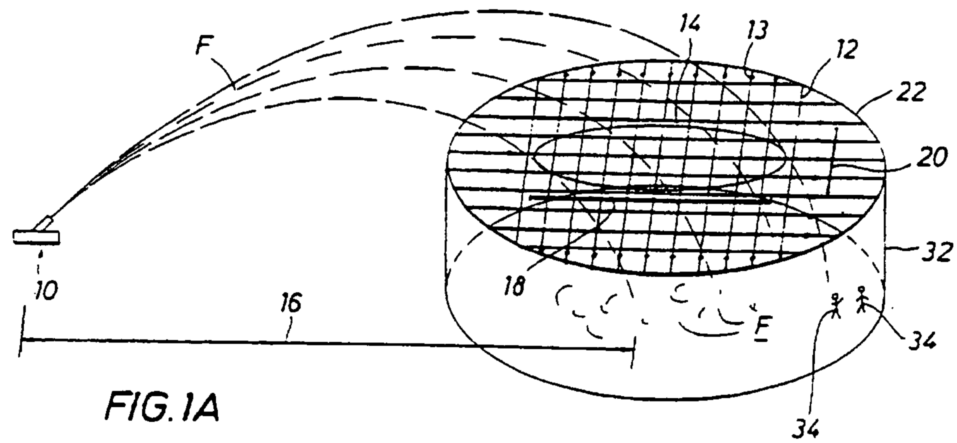

F
14
13
12
22
20
32
10
18
16
F
34
34

FIG.1A

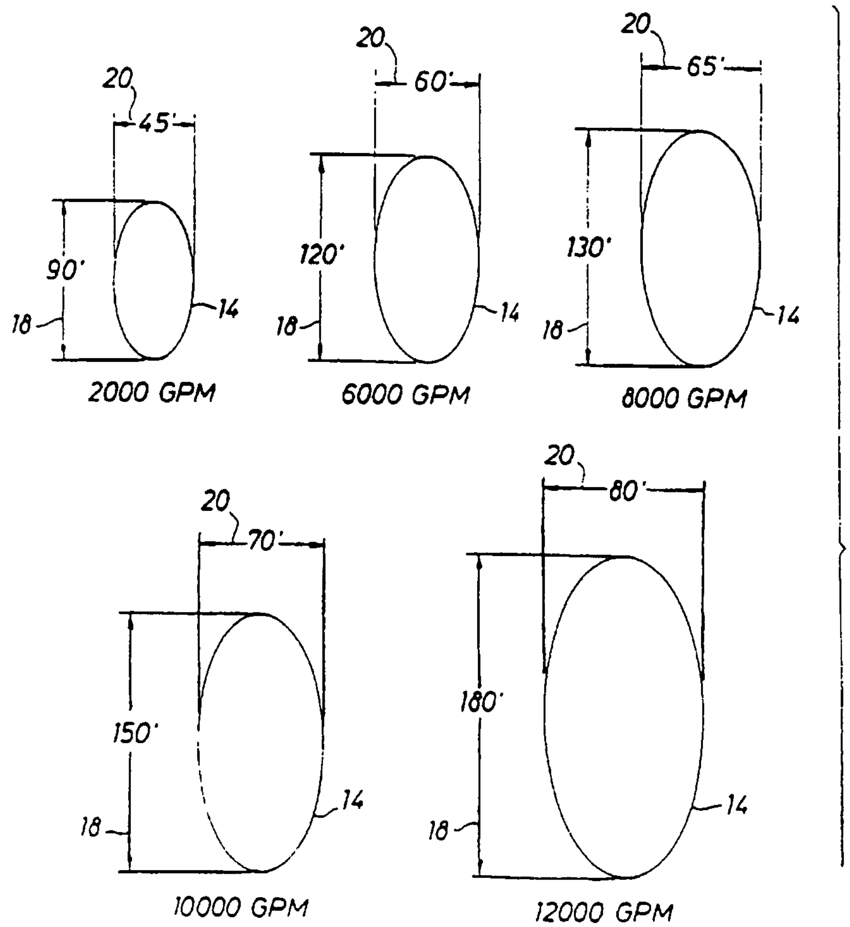

20
45'
90'
18
14
2000 GPM
20
60'
120'
18
14
6000 GPM
20
65'
130'
18
14
8000 GPM
20
70'
150'
18
14
10000 GPM
20
80'
180'
18
14
12000 GPM

FIG.1B

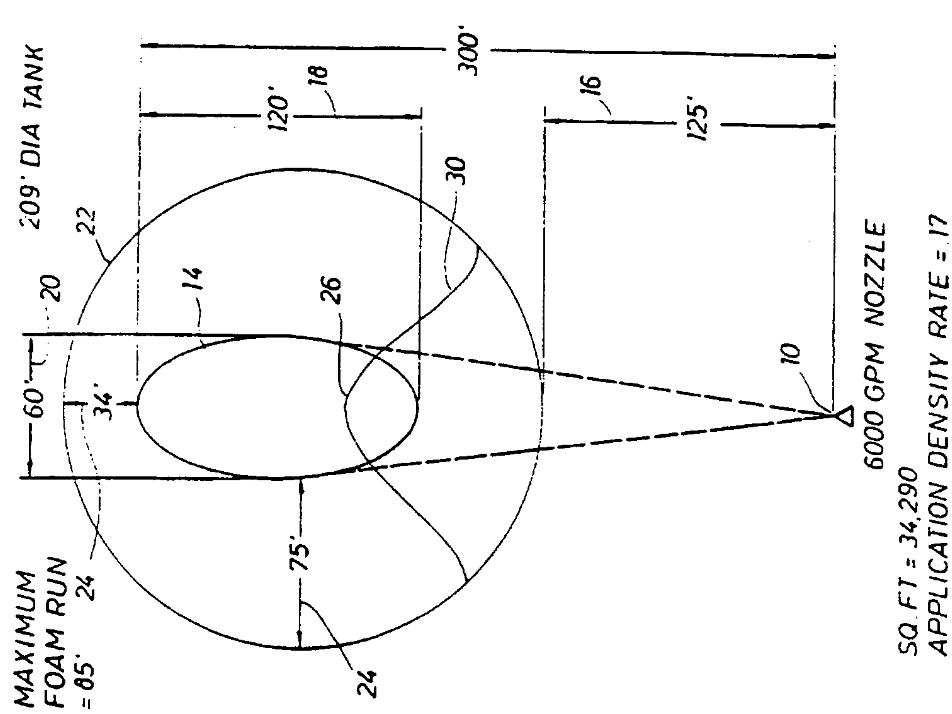

209' DIA TANK
MAXIMUM
FOAM RUN
= 85'
300'
120'
18
16
125'
22
20
14
26
30
60'
34'
24
75'
24
10
6000 GPM NOZZLE
SQ.FT = 34,290
APPLICATION DENSITY RATE = .17
MINIMUM APPLICATION = 5,829 GPM
FLOW = 6,000 GPM

FIG.2B

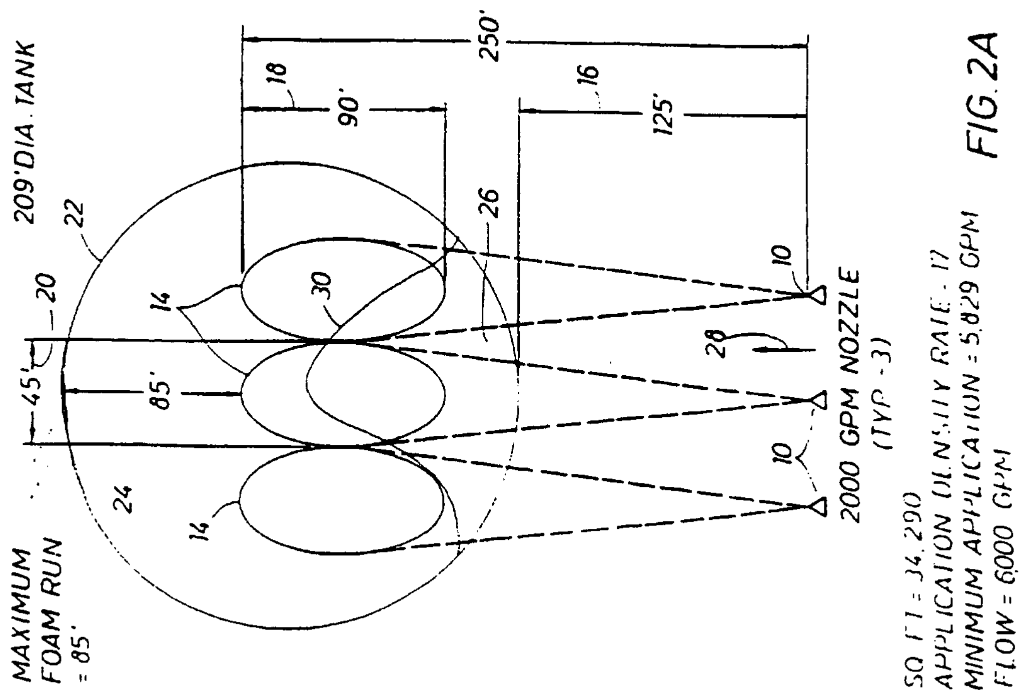
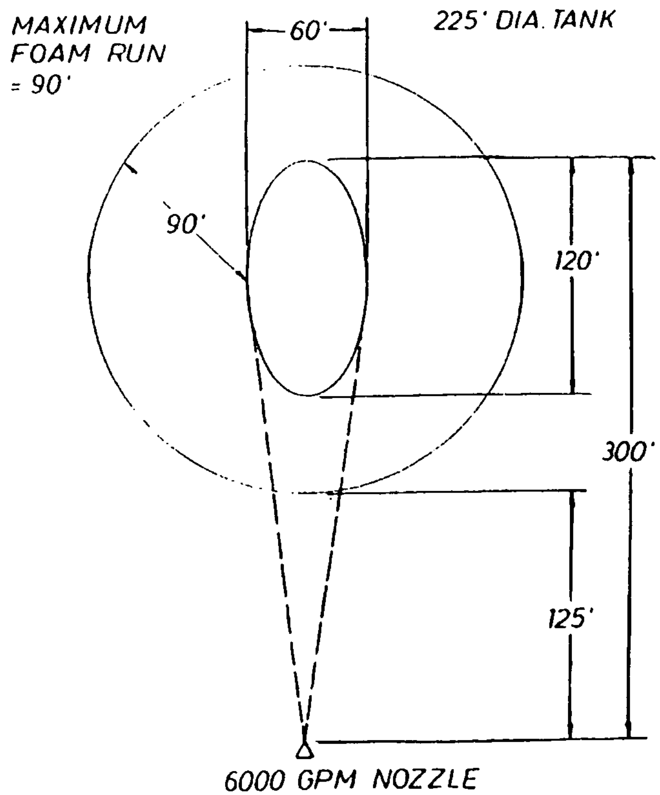
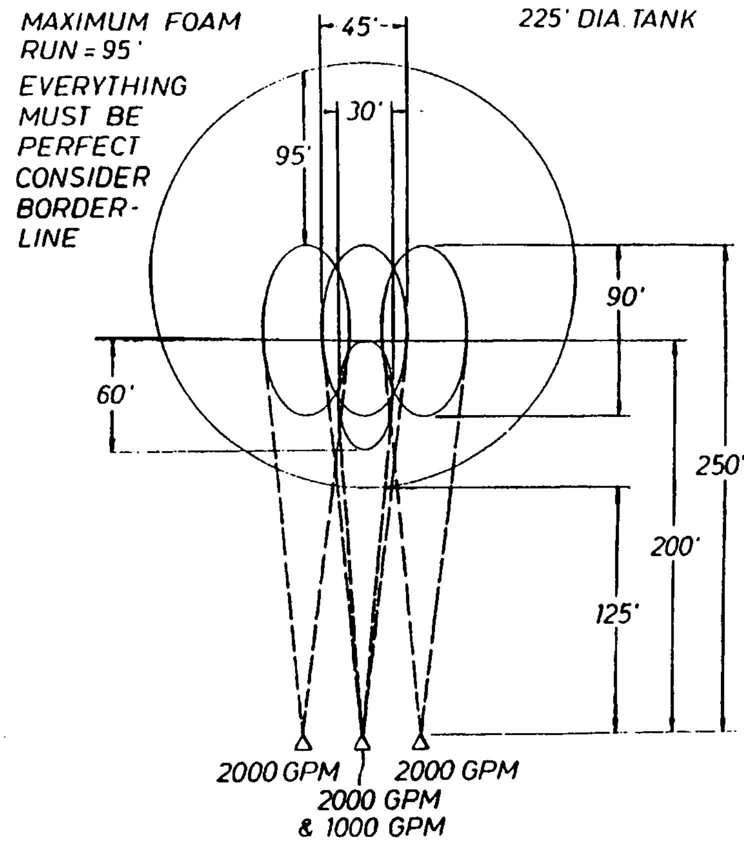

209'DIA.TANK
MAXIMUM
FOAM RUN
= 85'
250'
18
90'
16
125'
22
20
14
30
26
45'
85'
28
10
24
14
10
2000 GPM NOZZLE
(TYP -3)
SQ.FT = 34,290
APPLICATION DENSITY RATE = .17
MINIMUM APPLICATION = 5,829 GPM
FLOW = 6,000 GPM

FIG.2A



SQ FT = 39,741
APPLICATION DENSITY RATE = .15
MINIMUM APPLICATION = 5,961 GPM
FLOW = 6000 GPM

FIG. 2C



SQ. FT. = 39,741
APPLICATION DENSITY RATE = .18
MINIMUM APPLICATION = 7,153 GPM
FLOW = 7,000 GPM

FIG. 2D

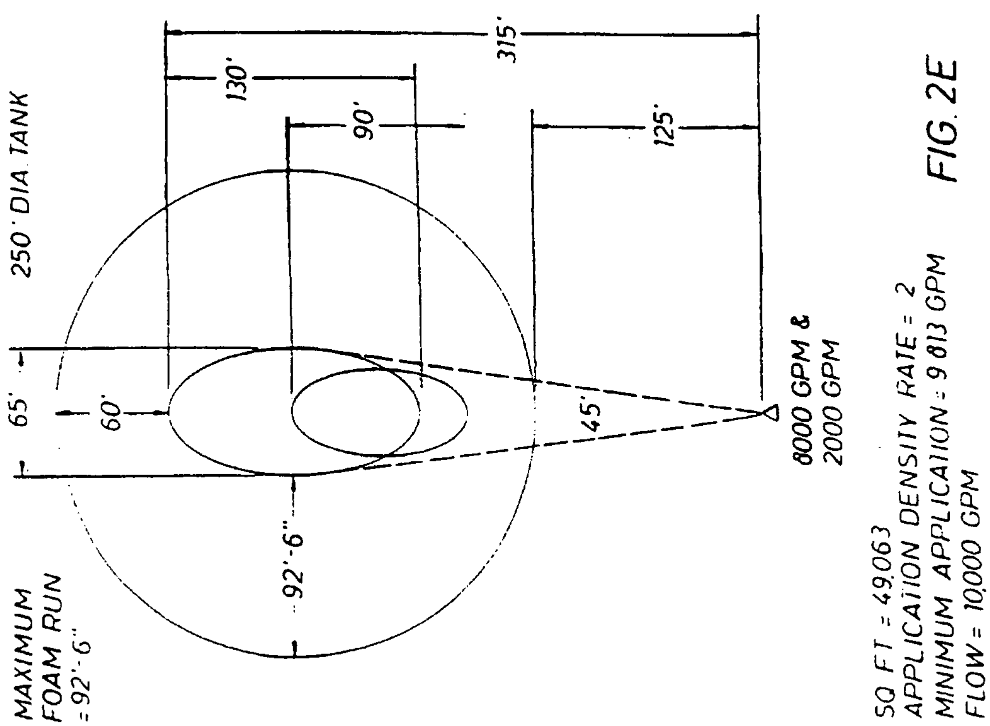

MAXIMUM
FOAM RUN
= 92'-6"
250' DIA TANK
65'
60'
92'-6"
90'
130'
315'
125'
45'
8000 GPM &
2000 GPM
SQ FT = 49,063
APPLICATION DENSITY RATE = .2
MINIMUM APPLICATION = 9,813 GPM
FLOW = 10,000 GPM

FIG. 2E

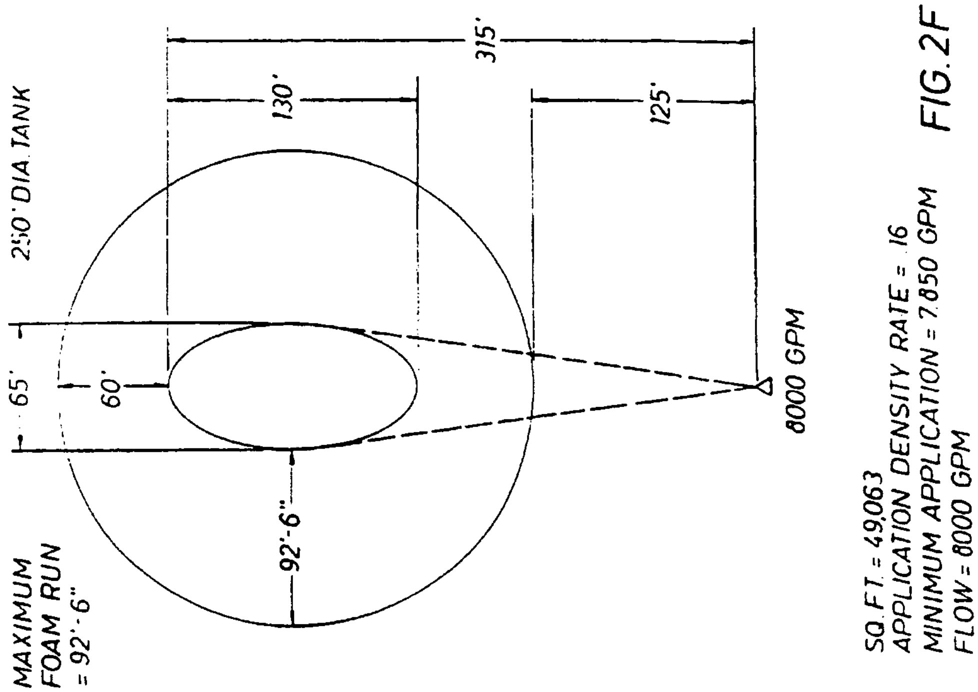
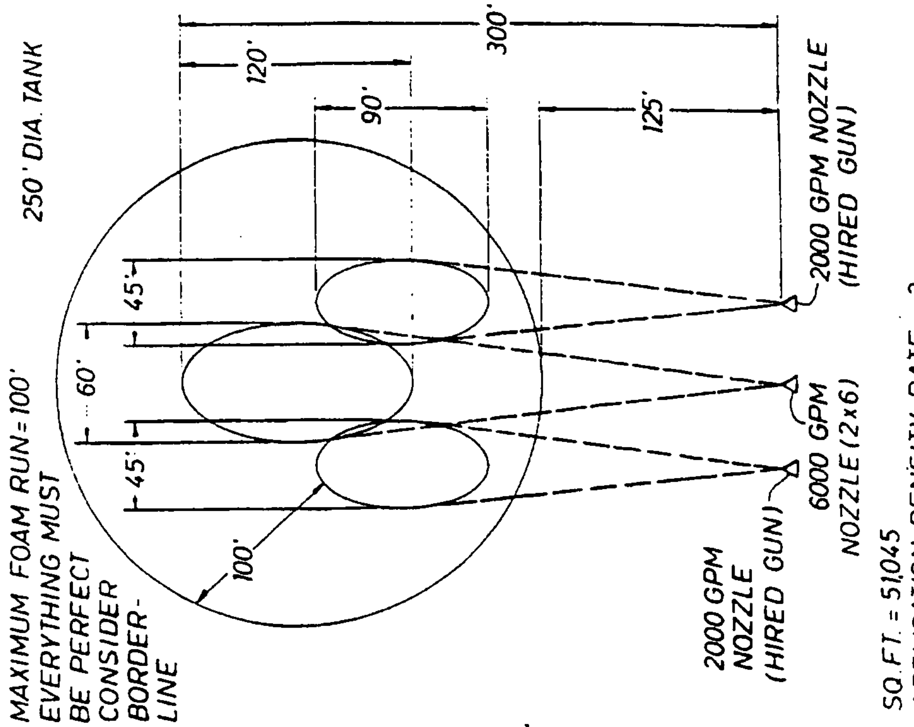
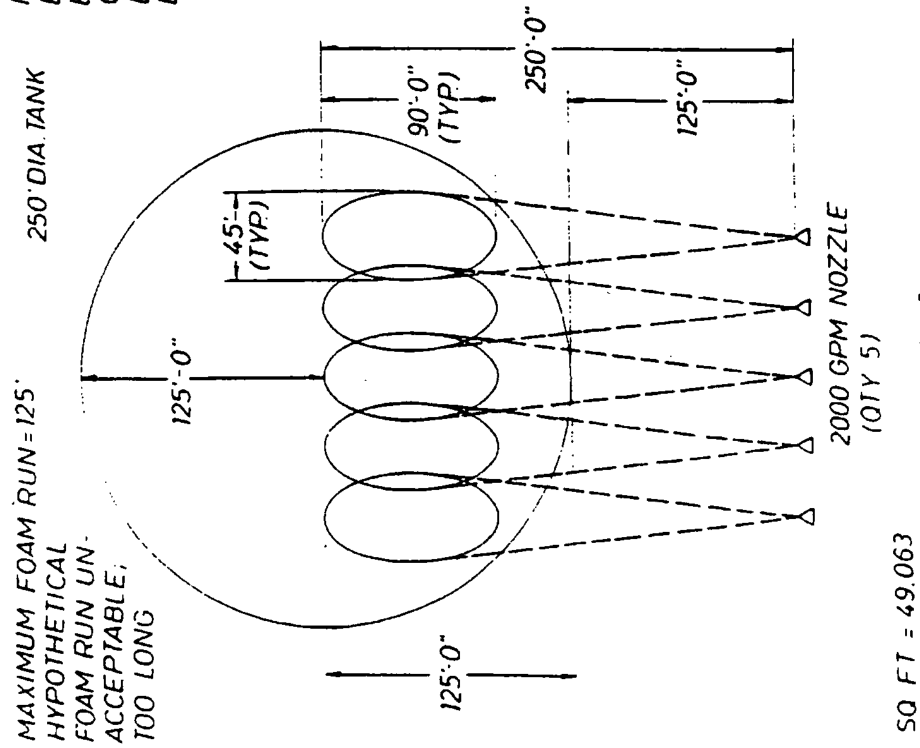

MAXIMUM
FOAM RUN
= 92'-6"
250' DIA TANK
65'
60'
92'-6"
130'
315'
125'
8000 GPM
SQ FT = 49,063
APPLICATION DENSITY RATE = .16
MINIMUM APPLICATION = 7,850 GPM
FLOW = 8000 GPM

FIG. 2F



250' DIA. TANK
MAXIMUM FOAM RUN=100' EVERYTHING MUST BE PERFECT CONSIDER BORDER-LINE
300'
120'
90'
125'
45'
60'
45'
100'
2000 GPM NOZZLE (HIRED GUN)
6000 GPM NOZZLE (2x6)
2000 GPM NOZZLE (HIRED GUN)
SQ. FT. = 51,045
APPLICATION DENSITY RATE = .2
MINIMUM APPLICATION = 10,209 GPM
FLOW = 10,000 GPM

FIG. 2H



250' DIA. TANK
MAXIMUM FOAM RUN=125' HYPOTHETICAL FOAM RUN UN-ACCEPTABLE, TOO LONG
250'-0"
90'-0" (TYP.)
125'-0"
45' (TYP.)
125'-0"
125'-0"
2000 GPM NOZZLE (QTY 5)
SQ. FT. = 49,063
APPLICATION DENSITY RAIL = .2
MINIMUM APPLICATION = 9,813 GPM
FLOW = 10,000 GPM

FIG. 2G

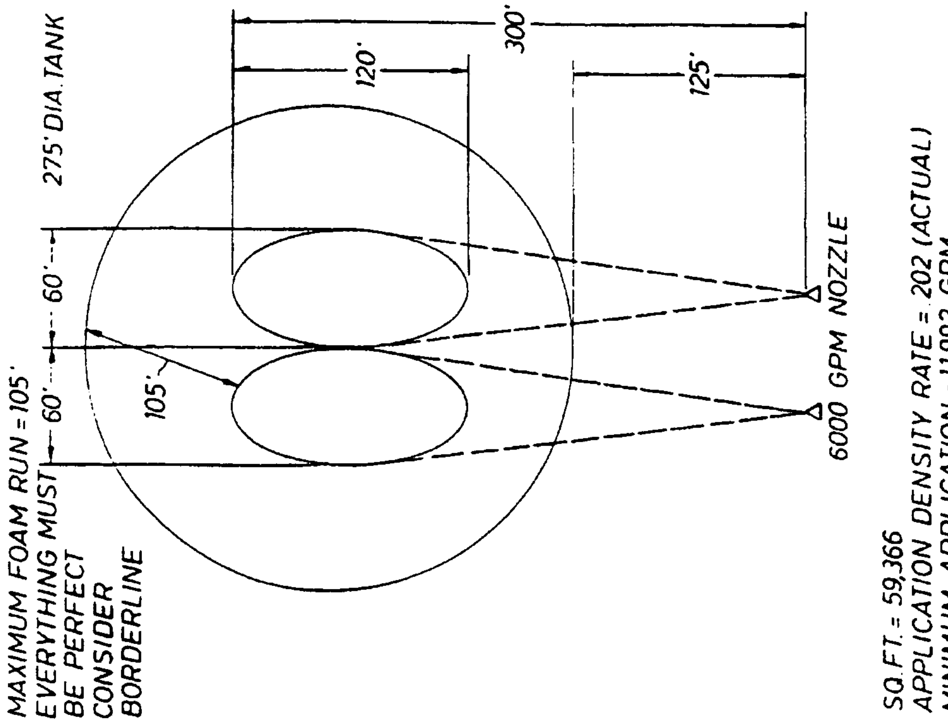

275' DIA. TANK
300'
120'
125'
60'
60'
105'
MAXIMUM FOAM RUN = 105'
EVERYTHING MUST
BE PERFECT
CONSIDER
BORDERLINE
6000 GPM NOZZLE
SQ.FT. = 59,366
APPLICATION DENSITY RATE = .202 (ACTUAL)
MINIMUM APPLICATION = 11,992 GPM
FLOW = 12,000 GPM

FIG. 2J

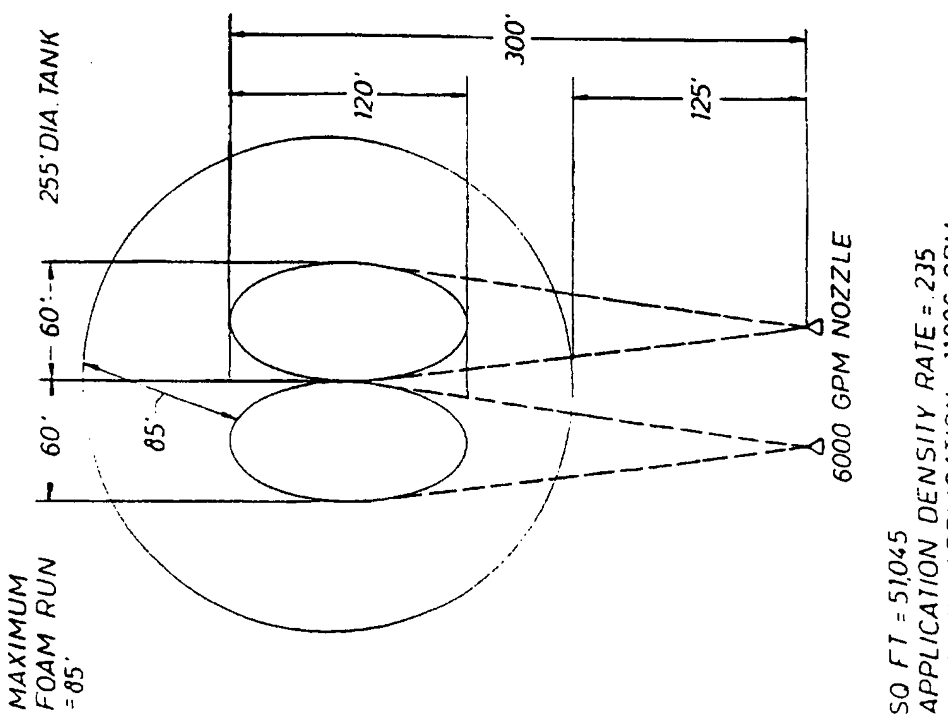

255' DIA. TANK
300'
120'
125'
60'
60'
85'
MAXIMUM
FOAM RUN
= 85'
6000 GPM NOZZLE
SQ FT = 51,045
APPLICATION DENSITY RATE = .235
MINIMUM APPLICATION = 11,996 GPM
FLOW = 12,000 GPM

FIG. 2I

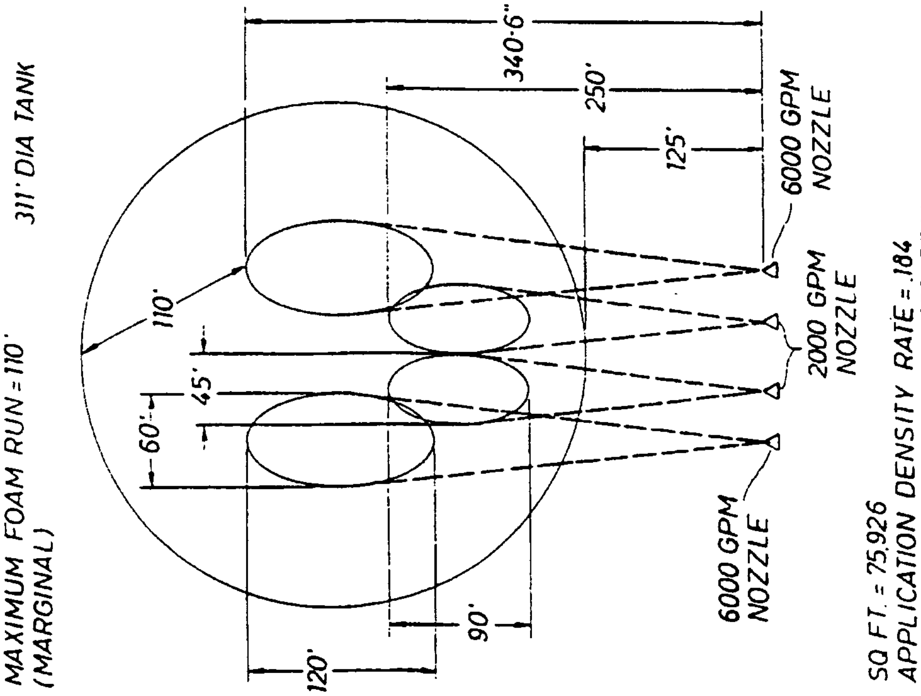

311' DIA TANK
MAXIMUM FOAM RUN = 110' (MARGINAL)
340'-6"
250'
125'
110'
45'
60'
90'
120'
6000 GPM NOZZLE
2000 GPM NOZZLE
6000 GPM NOZZLE
SQ FT = 75,926
APPLICATION DENSITY RATE = .184
MINIMUM APPLICATION = 13,970 GPM
FLOW = 14,000 GPM

FIG. 2L

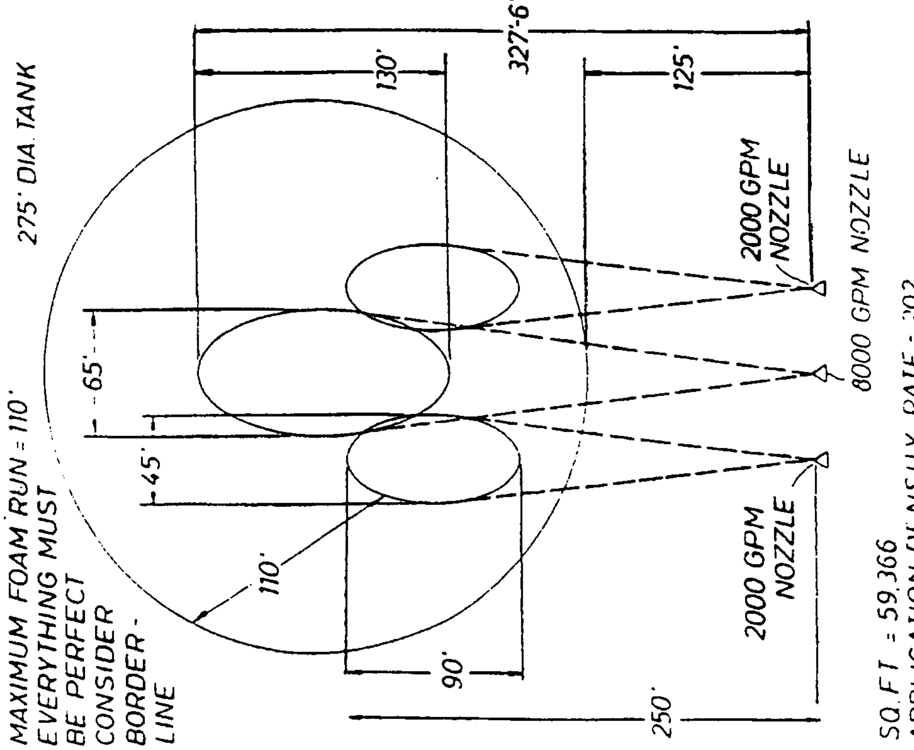
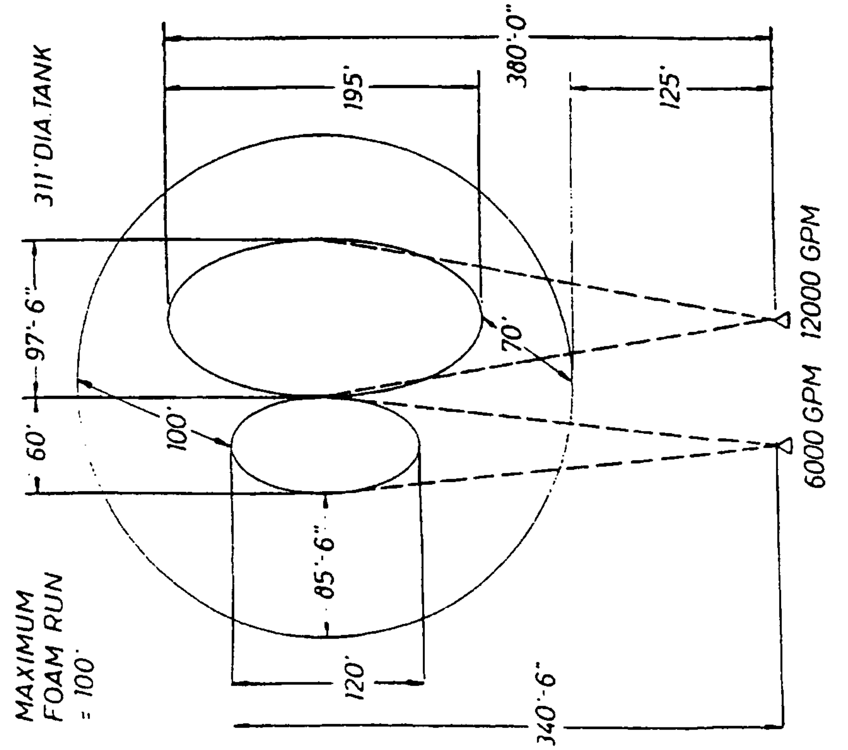
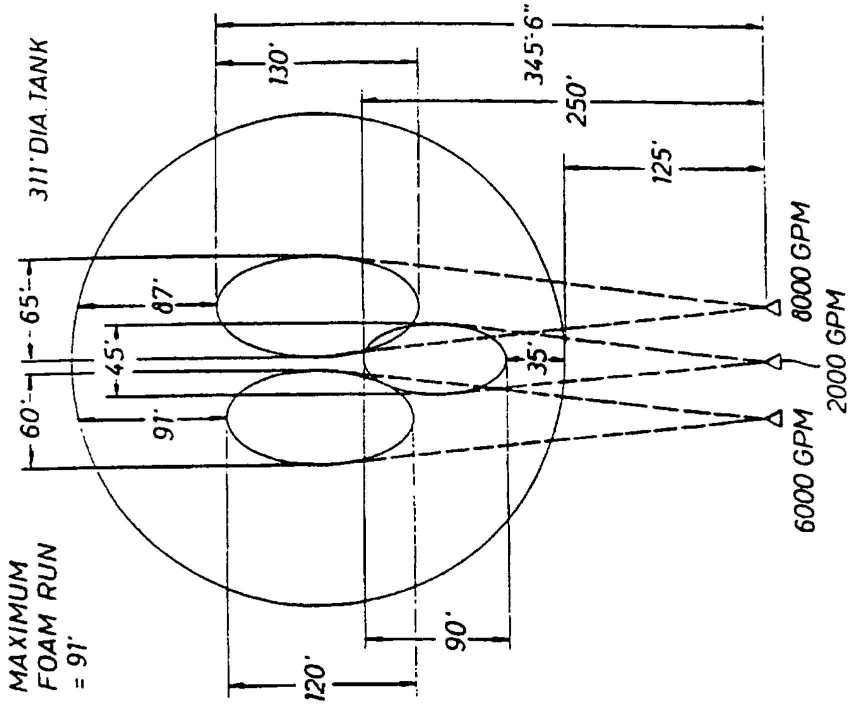

275' DIA TANK
MAXIMUM FOAM RUN = 110' EVERYTHING MUST BE PERFECT CONSIDER BORDER-LINE
327'-6"
130'
125'
65'
45'
110'
90'
250'
2000 GPM NOZZLE
8000 GPM NOZZLE
2000 GPM NOZZLE
SQ FT = 59,366
APPLICATION DENSITY RATE = .202
MINIMUM APPLICATION = 11,992 GPM
FLOW = 12,000 GPM

FIG. 2K



SQ. FT. = 75,926
APPLICATION DENSITY RATE = .24
MINIMUM APPLICATION = 18,222 GPM
FLOW = 18,000 GPM

FIG. 2M



SQ. FT. = 75,926
APPLICATION DENSITY RATE = .21
MINIMUM APPLICATION = 15,944 GPM
FLOW = 16,000 GPM

FIG. 2N

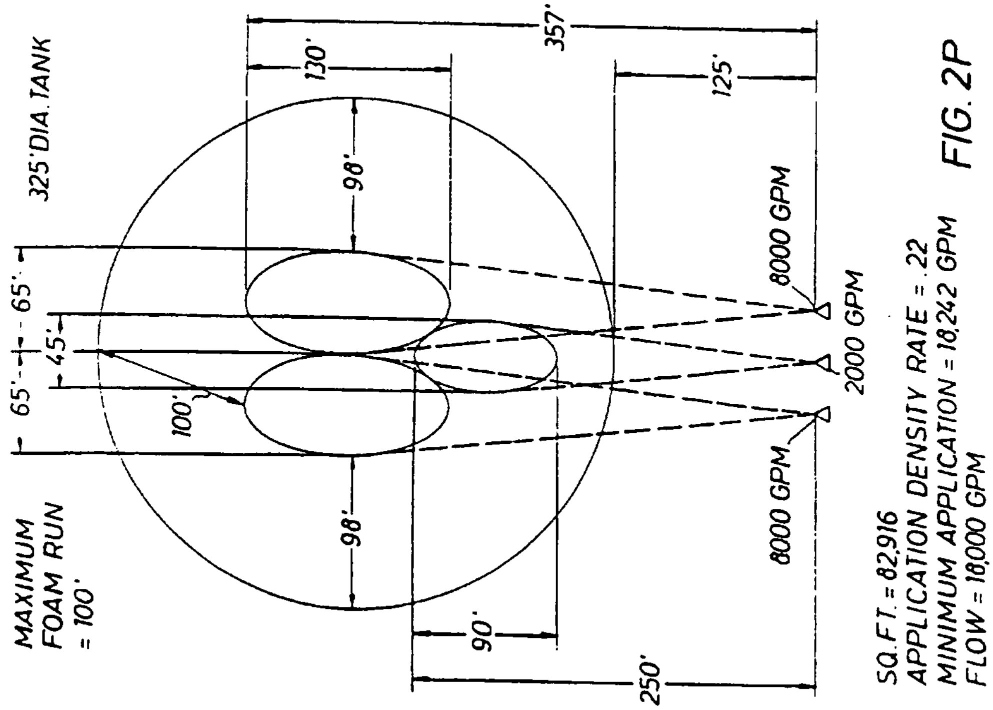

325' DIA. TANK
MAXIMUM FOAM RUN = 100'
65'
45'
65'
100'
98'
98'
130'
357'
125'
90'
250'
8000 GPM
2000 GPM
8000 GPM
SQ.FT. = 82,916
APPLICATION DENSITY RATE = .22
MINIMUM APPLICATION = 18,242 GPM
FLOW = 18,000 GPM

FIG. 2P

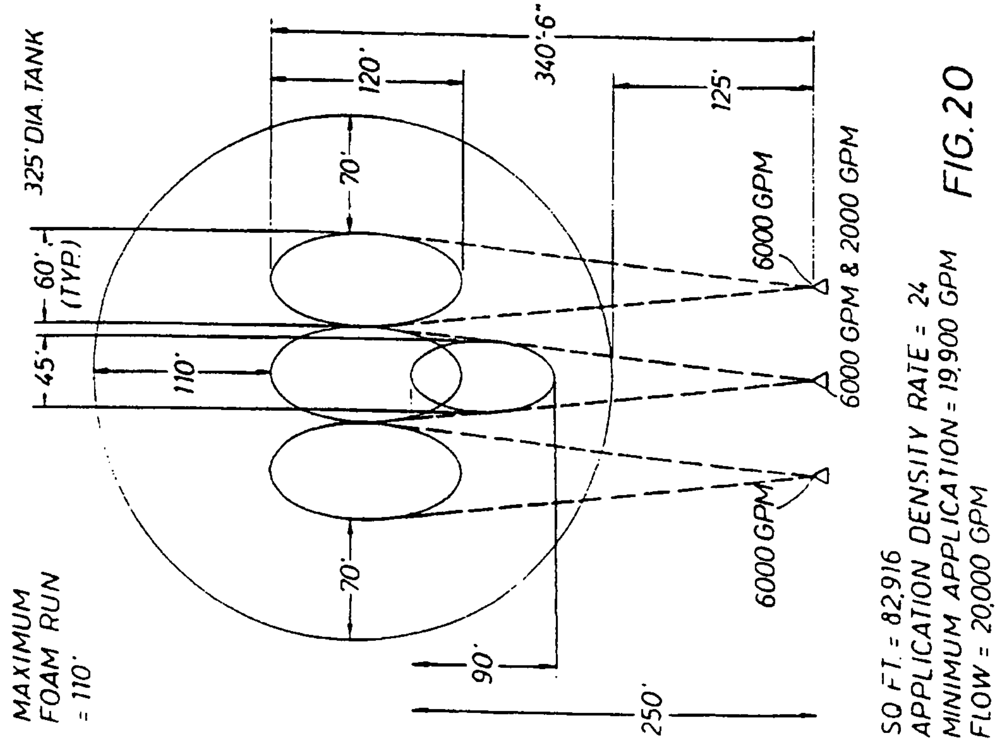
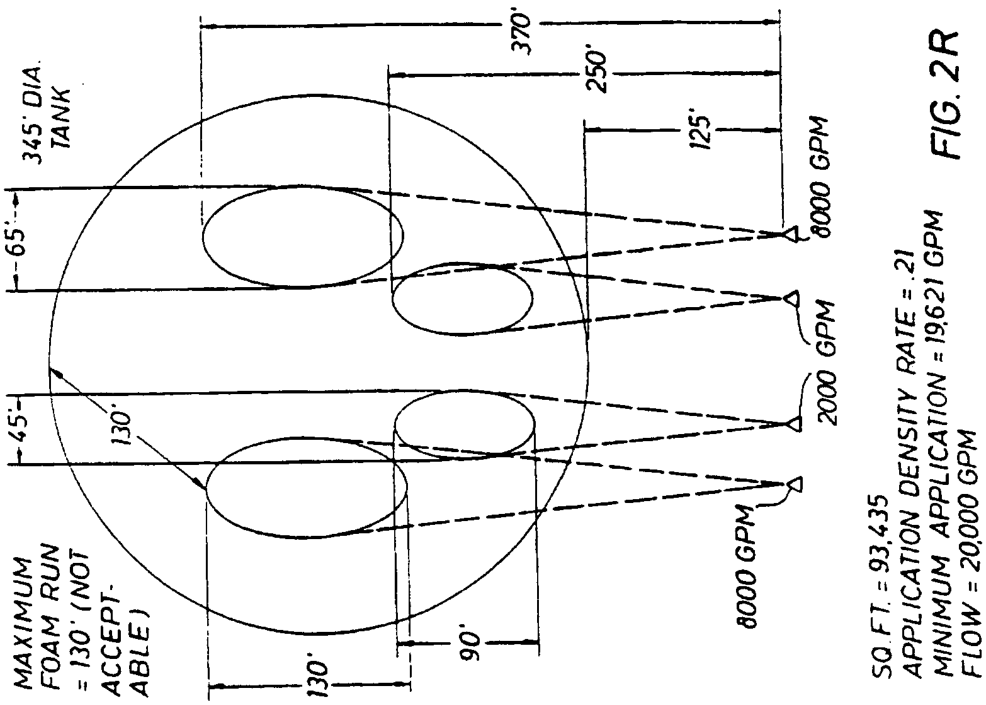
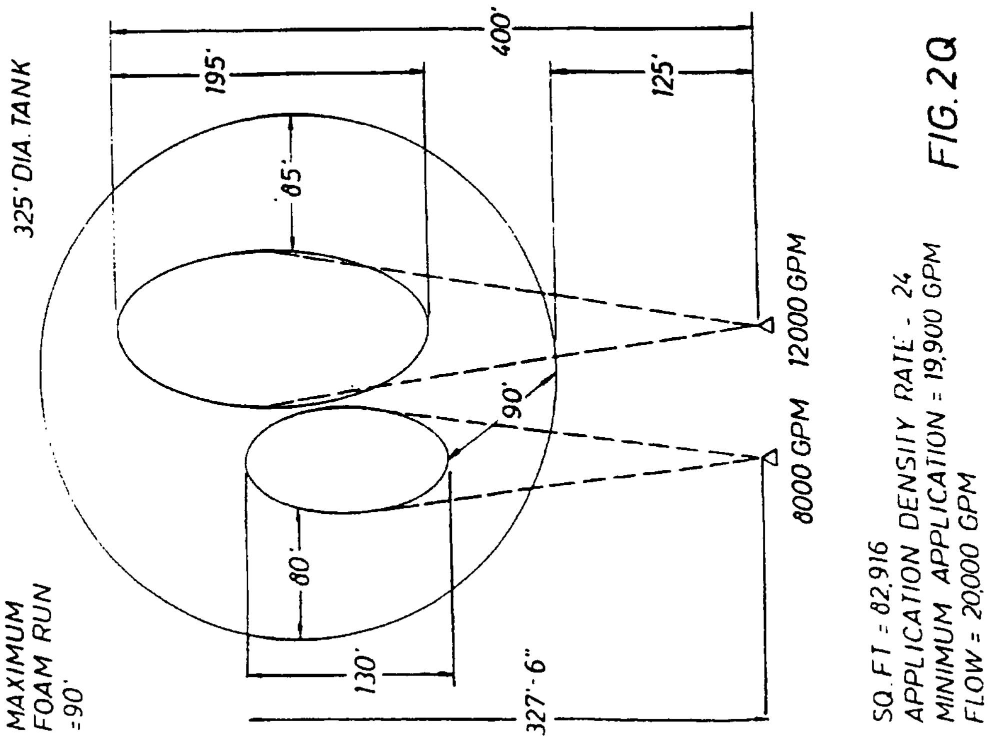

325' DIA. TANK
MAXIMUM FOAM RUN = 110'
45'
60' (TYP.)
110'
70'
70'
120'
340'-6"
125'
90'
250'
6000 GPM
6000 GPM & 2000 GPM
6000 GPM
SQ.FT. = 82,916
APPLICATION DENSITY RATE = .24
MINIMUM APPLICATION = 19,900 GPM
FLOW = 20,000 GPM

FIG. 2O



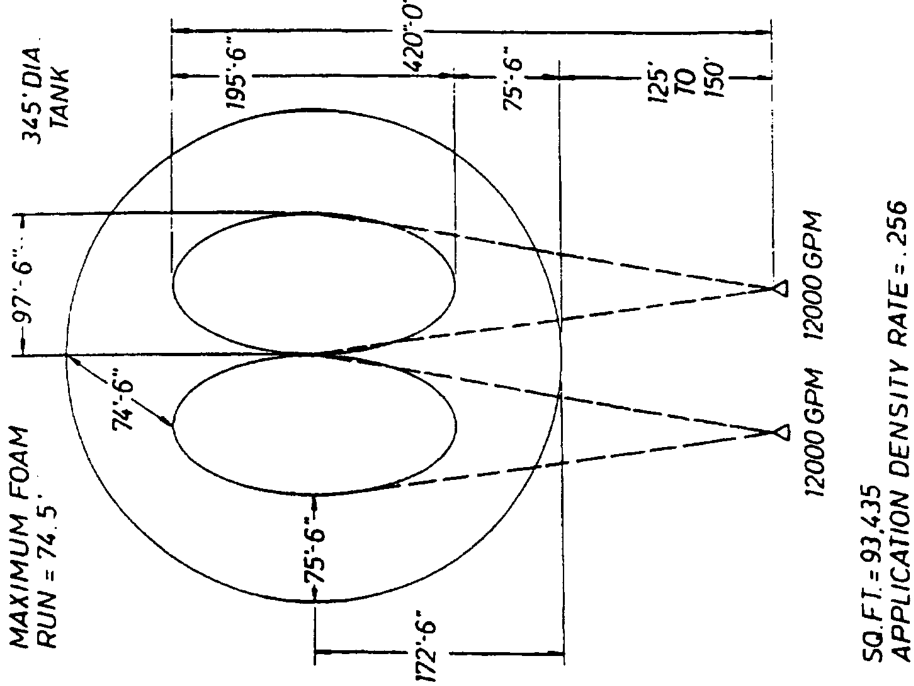
345' DIA. TANK
MAXIMUM FOAM RUN = 130' (NOT ACCEPT-ABLE)
65'
45'
130'
130'
90'
370'
250'
125'
8000 GPM
2000 GPM
2000 GPM
8000 GPM
SQ. FT. = 93,435
APPLICATION DENSITY RATE = .21
MINIMUM APPLICATION = 19,621 GPM
FLOW = 20,000 GPM

FIG. 2R



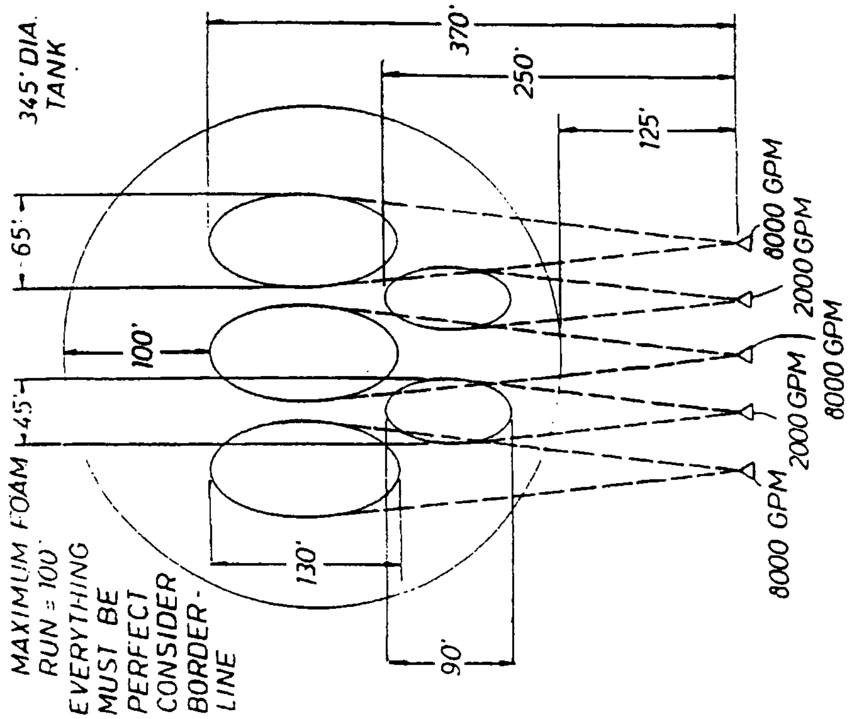
325' DIA. TANK
MAXIMUM FOAM RUN =90'
195'
400'
125'
85'
90'
80'
130'
327'-6"
12000 GPM
8000 GPM
SQ. FT = 82,916
APPLICATION DENSITY RATE - .24
MINIMUM APPLICATION = 19,900 GPM
FLOW = 20,000 GPM

FIG. 2Q



SQ.FT. = 93,435
APPLICATION DENSITY RATE = .256
MINIMUM APPLICATION = 23,920 GPM
FLOW = 24,000 GPM

FIG. 2T



SQ FT = 93,435
APPLICATION DENSITY RATE = 3
MINIMUM APPLICATION = 28,031 GPM
FLOW = 28,000 GPM

FIG. 2S

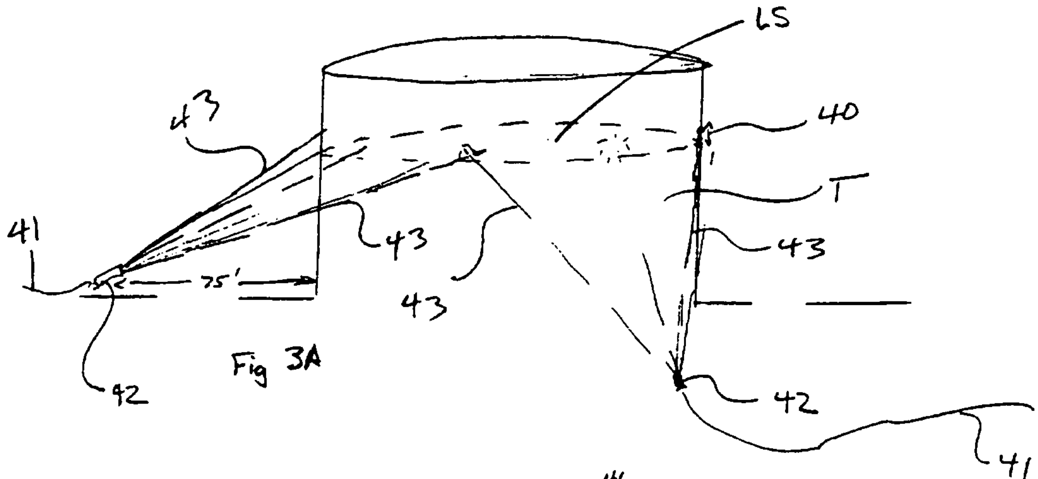


Fig 3A

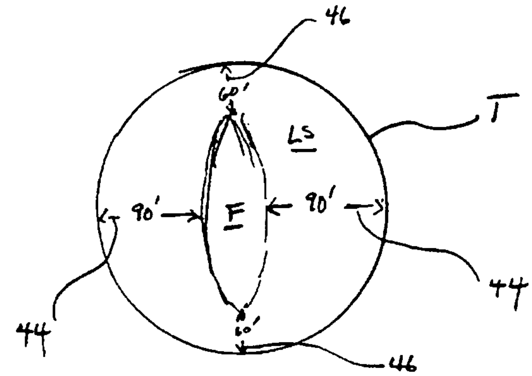


Fig 3B

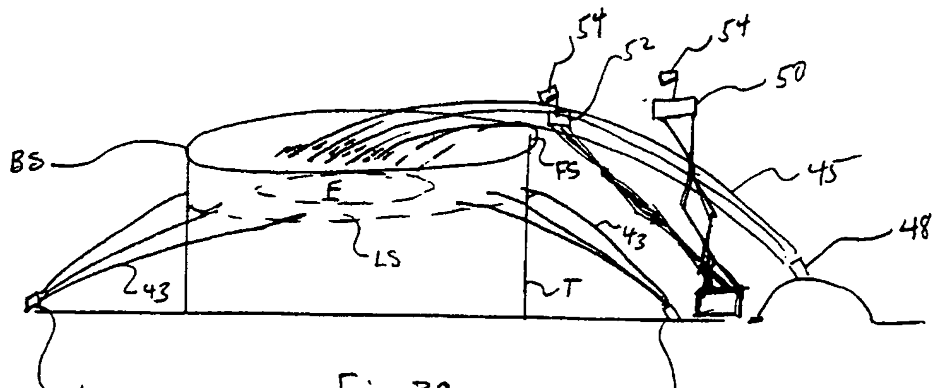


Fig 3C

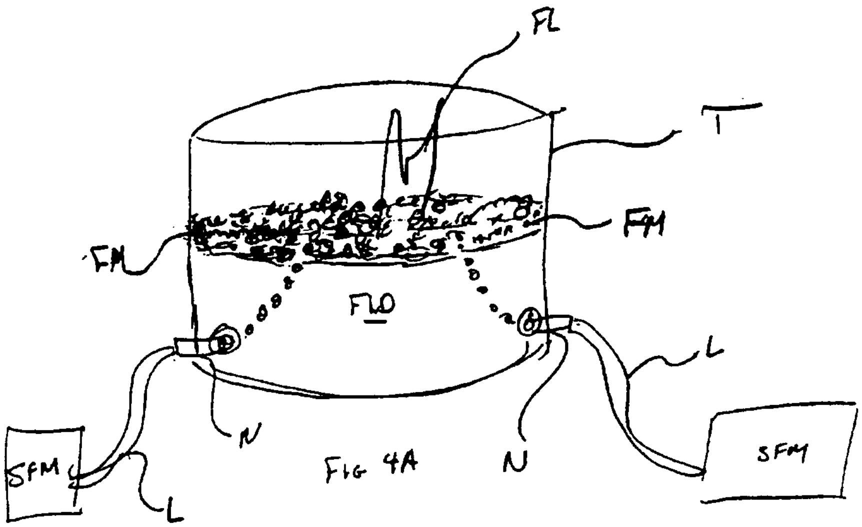


Fig 4A

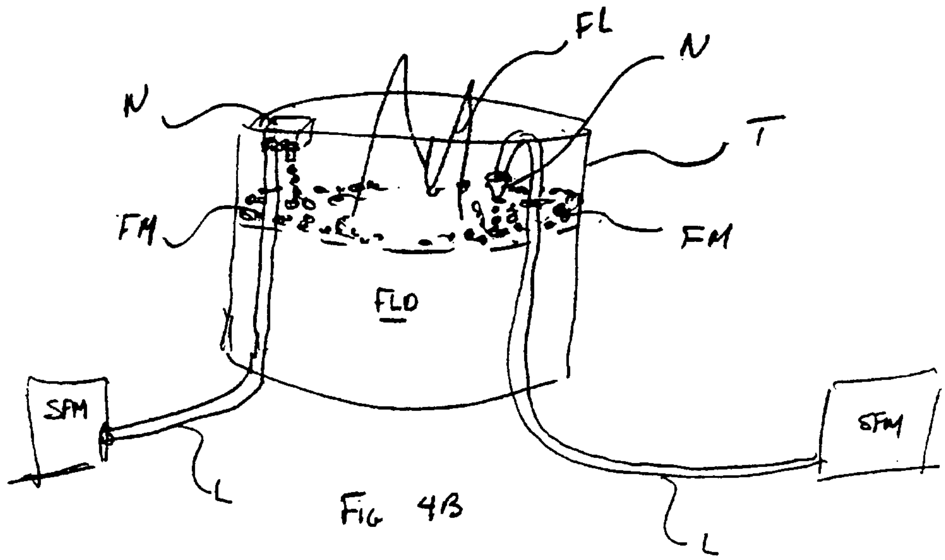


Fig 4B

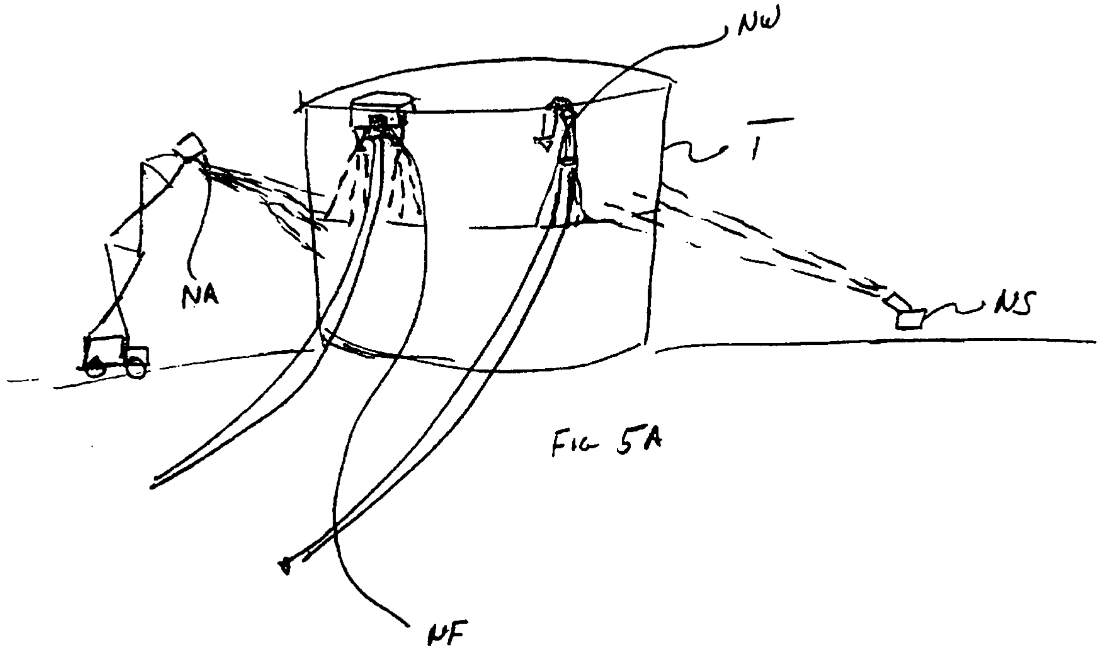


Fig 5A

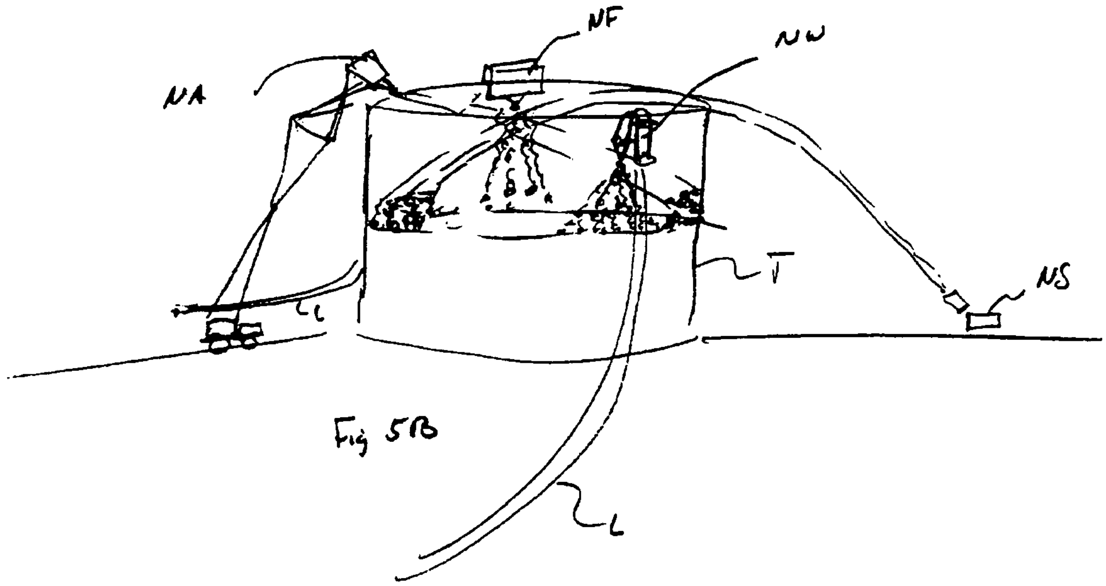


Fig 5B

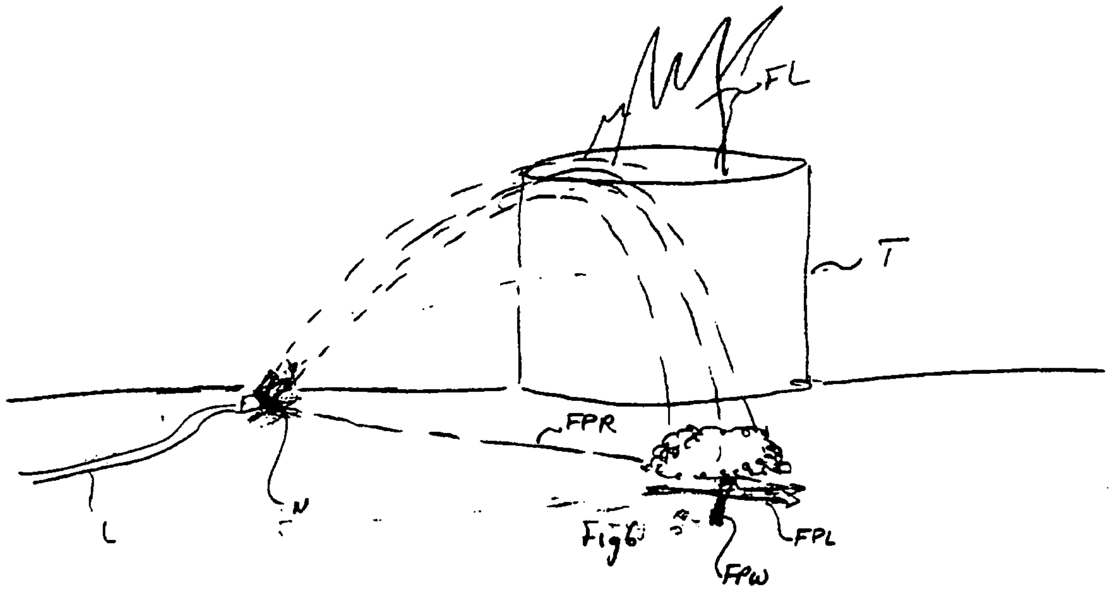


Fig 6

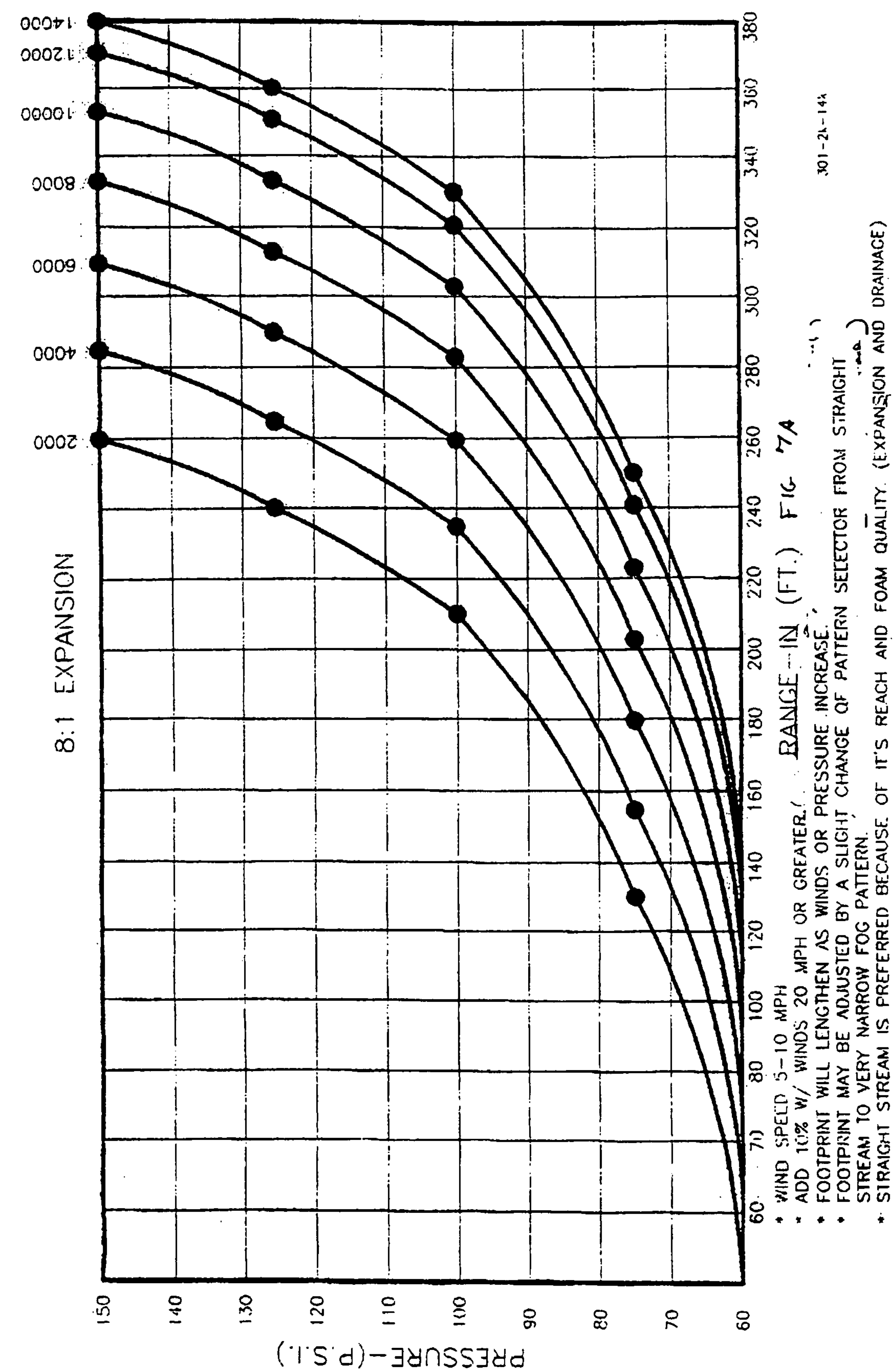

8:1 EXPANSION
2000
4000
6000
8000
10000
12000
14000
RANGE - IN (FT.)
60 70 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380
PRESSURE-(P.S.I.)
150 140 130 120 110 100 90 80 70 60
* WIND SPEED 5-10 MPH
* ADD 10% W/ WINDS 20 MPH OR GREATER.
* FOOTPRINT WILL LENGTHEN AS WINDS OR PRESSURE INCREASE.
* FOOTPRINT MAY BE ADJUSTED BY A SLIGHT CHANGE OF PATTERN SELECTOR FROM STRAIGHT STREAM TO VERY NARROW FOG PATTERN.
* STRAIGHT STREAM IS PREFERRED BECAUSE OF IT'S REACH AND FOAM QUALITY. (EXPANSION AND DRAINAGE)

FIG 7A

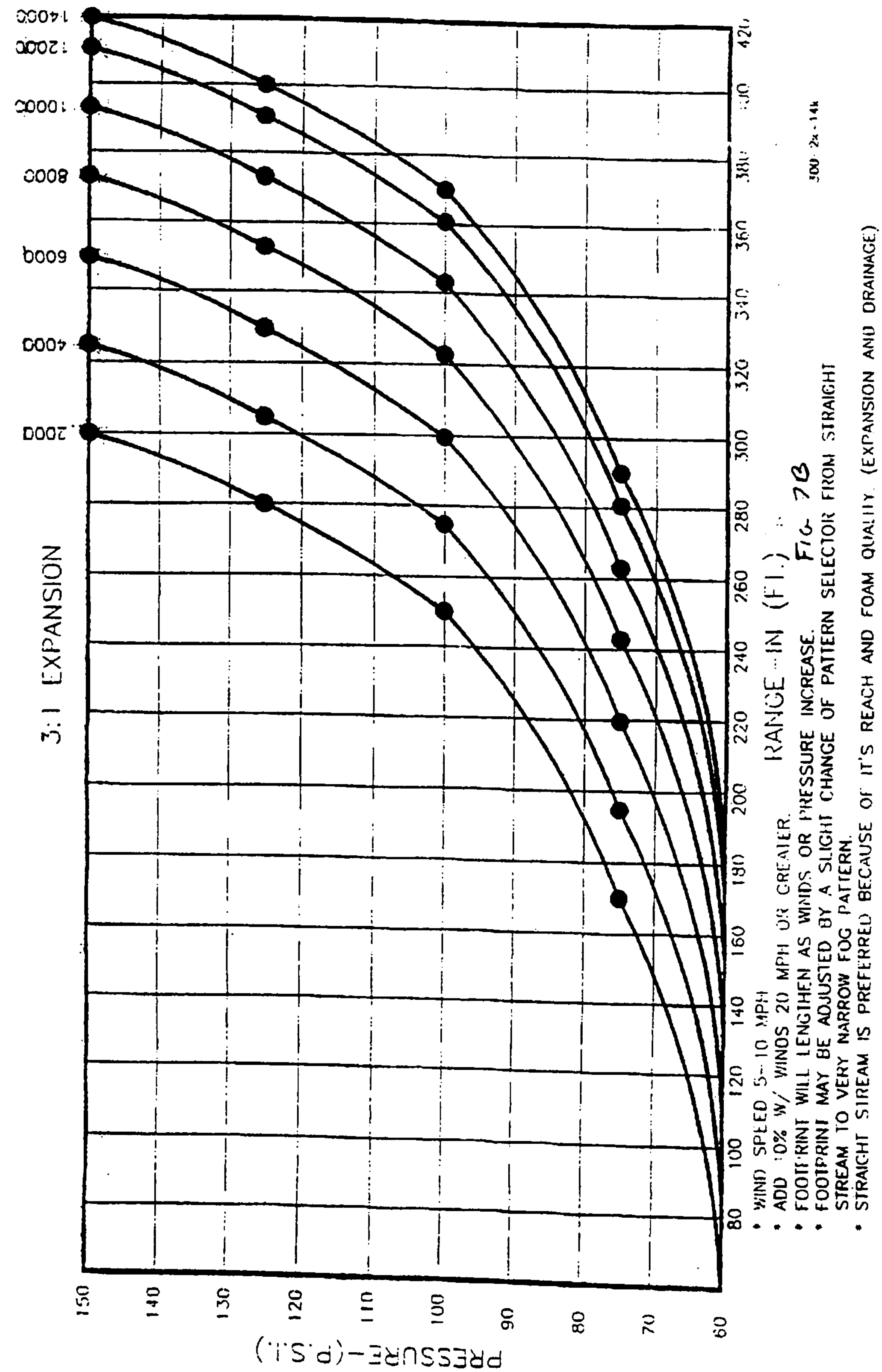

3:1 EXPANSION
2000
4000
6000
8000
10000
12000
14000
PRESSURE–(P.S.I.)
150
140
130
120
110
100
90
80
70
60
RANGE – IN (FT.)
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
• WIND SPEED 5–10 MPH
• ADD 10% W/ WINDS 20 MPH OR GREATER.
• FOOTPRINT WILL LENGTHEN AS WINDS OR PRESSURE INCREASE.
• FOOTPRINT MAY BE ADJUSTED BY A SLIGHT CHANGE OF PATTERN SELECTOR FROM STRAIGHT STREAM TO VERY NARROW FOG PATTERN.
• STRAIGHT STREAM IS PREFERRED BECAUSE OF IT'S REACH AND FOAM QUALITY. (EXPANSION AND DRAINAGE)

FIG. 7B

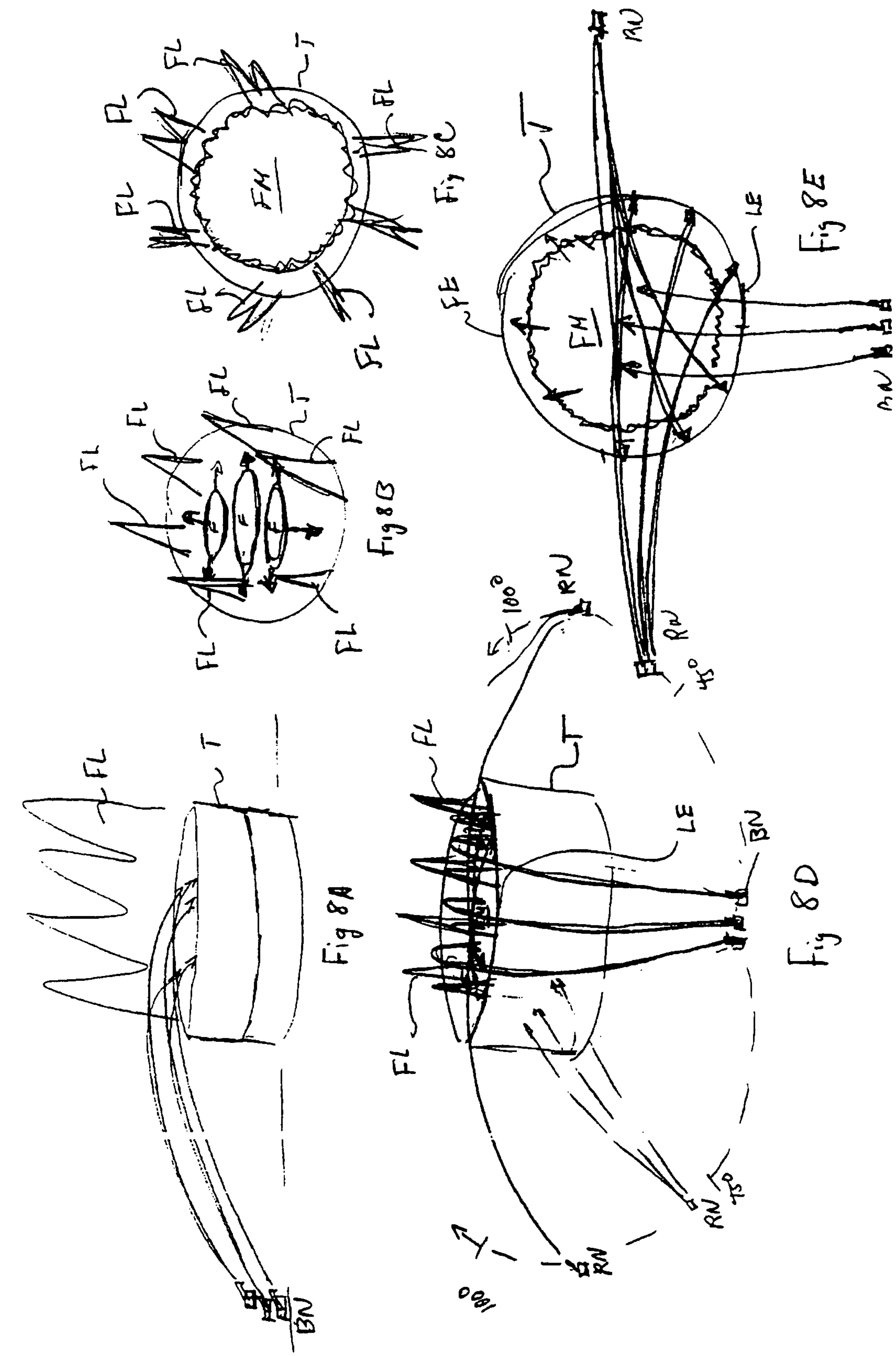


Fig 8A

Fig 8B

Fig 8C

Fig 8D

Fig 8E

Sheet2

Foam Test Results (On MTBE)					
Foam Type	% Concentrate	Control Time in Sec	Ext time in Sec	Foam Expansion	25% D.T. in Sec
3M ATC	3%	25	291	5.45	345
3M ATC	6%	25	311	5.55	789
3M 3X3	3%	30	254	5.59	364
3M 3X3	6%	20	217	5.59	614

Fig 9A

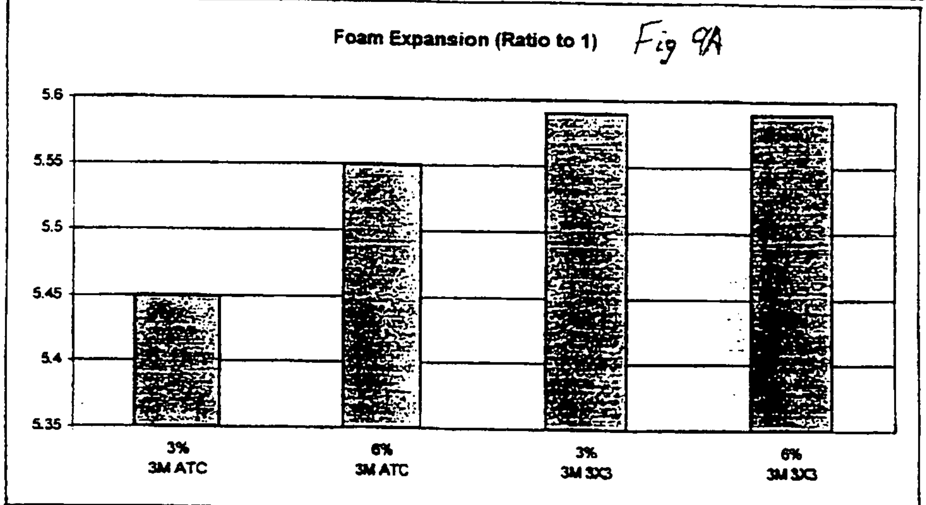


Fig 9B

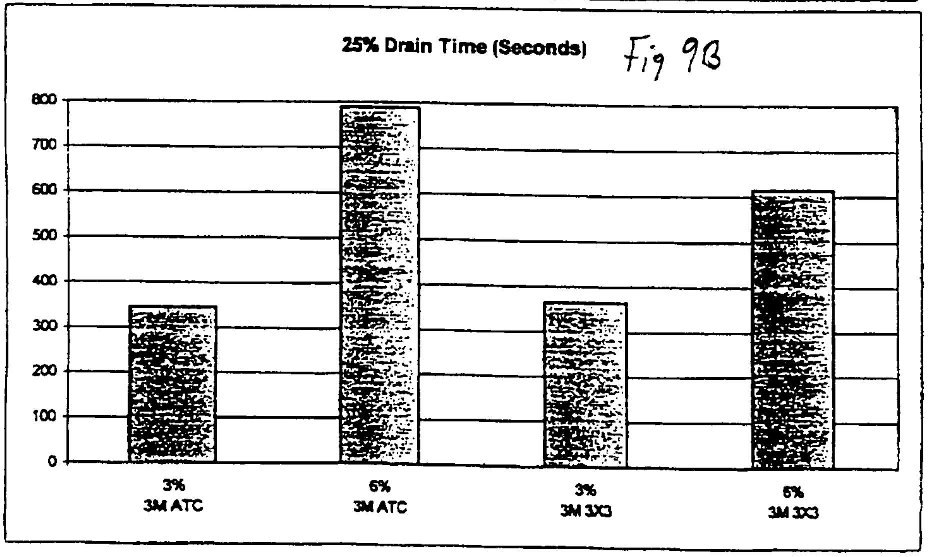
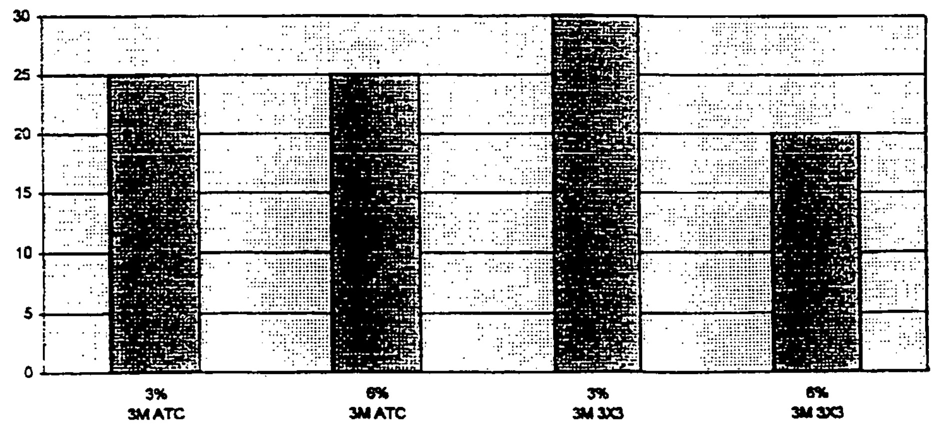


Fig 9C

Sheet3

Foam Test Results (On MTBE)					
Foam Type	% Concentrate	Control Time in Sec	Ext time in Sec	Foam Expansion	25% D.T. in Sec
3M ATC	3%	25	291	5.45	345
3M ATC	6%	25	311	5.55	789
3M 3X3	3%	30	254	5.59	364
3M 3X3	6%	20	217	5.59	614

Control Time (Seconds) Fig 9D



Extinguishment Time (Seconds) Fig 9E

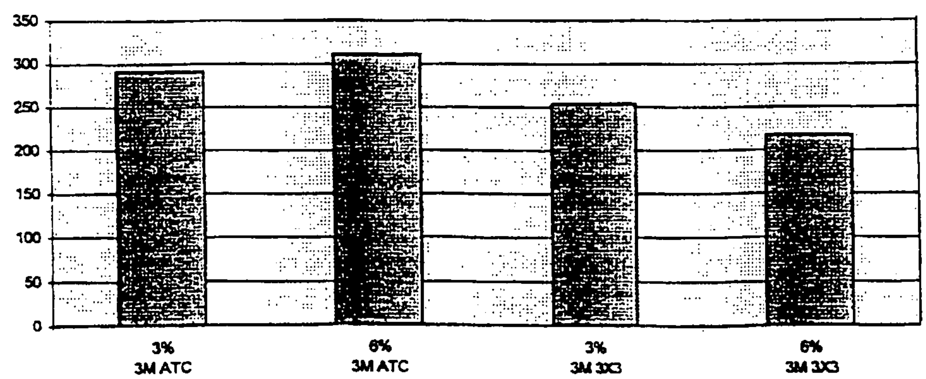


Fig 9F

INTERNATIONAL SEARCH REPORT	International application No. PCT/US96/19691

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :A 62 C 3/06
US CL :169/46, 47, 66, 67, 68
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 169/46, 47, 66, 67, 68

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	SU 1,400,621 A (KUPRIN et al.) 7 June 1988, entire document	1, 4, 5 ---------- 6, 10
X --- Y	SU 1,416,129 A (VOLOSHANENKO et al.) 15 August 1988, entire document	2 --------- 4, 6, 8-10
Y	US 1,775,846 A (BLAW) 16 September 1930, entire document	4
Y	US 4,781,252 A (WILBURN et al.) 1 November 1988, entire document	8, 9
A	SU 1,553,145 A (BEZRODIYI et al.) 30 March 1990	NONE

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 FEBRUARY 1997	25 FEB 1997
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer GARY C. HOGE
Facsimile No. (703) 305-3230	Telephone No. (703) 308-1113

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	SU 1,335,300 A (ZOZULYA et al.) 7 September 1987	NONE
A	US 1,714,015 A (GALLAGHER) 21 May 1929	NONE